DESIGN A FALLING FILM HEAT EXCHANGER

By

YASSER BAHAMDAN	**Comp. No. 0908715**
MOHAMMED ALSHIEKH	**Comp. No. 0908762**
MOHAMMED JAMBI	**Comp. No. 0909116**
ABDULLAH ALSHARIEKH	**Comp. No. 0910777**
AMJAD MELEBARI	**Comp. No. 0908724**

Supervised by

Dr. HANI SAITand Prof. YACINE KHETIB

Advisory committee

Prof. YACINE KHETIB	**THERMAL ENG, FoE-KAU**
Dr. NEDIM TURKMEN	**THERMAL ENG, FoE-KAU**

Customer

DR.HANI SAIT	**THERMAL ENG, FoE-KAU**

MECHANICAL ENGINEERING DEPARTMENT

THERMAL ENGINEERING AND DESALINATION TECNOLOGY PROGRAM

FACULTY OF ENGINEERING
KING ABDULAZIZ UNIVERSITY
JEDDAH - SAUDI ARABIA

SUMMER 1434-35 H – 2013-14 G

DESIGN A FALLING FILM HEAT EXCHANGER

By

YASSER BAHAMDAN	**Comp. No. 0908715**
MOHAMMED ALSHIEKH	**Comp. No. 0908762**
MOHAMMED JAMBI	**Comp. No. 0909116**
ABDULLAH ALSHARIEKH	**Comp. No. 0910777**
AMJAD MELEBARI	**Comp. No. 0908724**

A senior project report submitted in partial fulfillment
Of the requirements for the degree of
BACHELOR OF SCIENCE
In
MECHANICAL ENGINEERING (Thermal Engineering and Desalination Technology) PROGRAM

Supervised by:

Dr. HANI SAIT ………………………………….

Prof. YACINE KHETIB ………………………………….

Approved by:

Dr. NEDIM TURKMEN ………………………………….

MECHANICAL ENGINEERING DEPARTMENT

THERMAL ENGINEERING AND DESALINATION TECNOLOGY PROGRAM

FACULTY OF ENGINEERING
KING ABDULAZIZ UNIVERSITY
JEDDAH - SAUDI ARABIA

SUMMER 1434-35 H – 2013-14 G

بسم الله الرحمن الرحيم

الــحــمــد لله رب

الــعــالــمــيــن

و الصلاة و السلام على أشرف الأنبياء و المرســلين سيدنا محمد و على آله و صحبه أجمعين

قال الله تعالى في كتابه الكريم

{يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ} [المجادلة: 11]

Acknowledgement

Thanks to Allah, the most Gracious and most Merciful. Firstly, we pray to Allah for His guidance and protection throughout our life. We glorify His name through this small accomplishment. We ask Him, with hope only in Him, to accept our efforts. Secondly, peace and blessing be upon His Prophet Mohammed. Thirdly, we thank our parents for their patience and endless support. Thanks to Dr. Hani Sait and Dr. YacineKhetib our advisors for guiding this work with his knowledge and experience, also we thank Dr.Nadeem Turkmen to advise and support us in writing processes of this report. Finally, we thank all whom who helped us, directly and indirectly, to accomplish this work especially Mechanical Engineering Department, Chairman and faculty members.

EXECUTIVE SUMMARY

A small scale falling film heat exchanger is designed to beused in domestic and industrial applications as a main objective of this project. Another objective is to optimize the tube spacing and liquid flow rate influence on falling film formation with heated water should not exceed 43^{o}C, a maximum flow rate from a cooling path is 4 kg/min, and a minimum flow rate from the falling film at 1 kg/ min. This objective is to increasethe heat transfer coefficient. A test box was built consisting of test section and the test section consisted of feed tubes, test tubes and tank.All the tubes are made of copper, which has a high thermal conductivity. The feed tube is setup above the test section, its height is 300 mm the length is 400 mm and the width is 100mm, a line of holes were drilled 2 mm apart from each other, providing26 holes.The feed tube has inside and outside diameters of 12.7 mm and 10 mm. It receives liquid from a cooling path. Three test tubes configured above each other with diameter of 12.7 mm are placed at a pitch of 130 mm under the feed tubes. They were all held by the supporting box, which was made of transparentplastic glasses. The cooling path gave the capability of adjusting the temperature and to keep it constant.It was used to supply hot water inside the test tubes. A constant temperature tap water provides pure water to the outside of the test tubes with different flow rate as shown in the following figure.

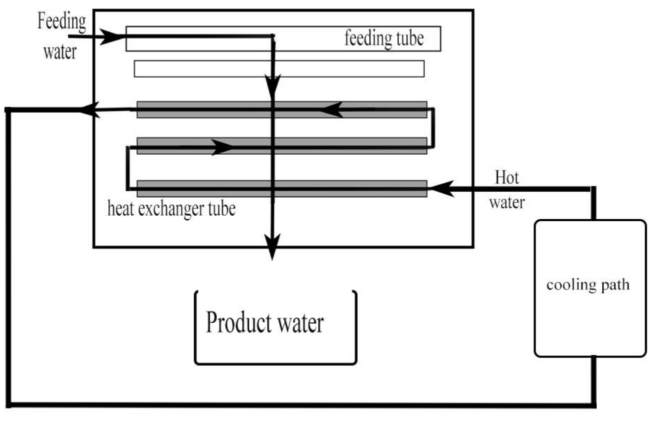


Figure: The circuit of falling film heat exchange

Outlet temperature and flow rate of water, inside and outside the test tubes were recorded. Surface temperature was measured for one tube. Data acquired was used for temperature measurement.

For good results we chose a copper tube for the internal horizontal tubes, which we named it "test tube",for more accurate readings, the test tubes were setup to be movable, transparent neon fiberglass as the box material and double groove for the internal tubes surface. After studying the falling form, we decide to set the falling as a sheet jet.

This type of heat exchanger is Innocuous to the environment, with no side effects because it consists of few and simple parts. Falling film heat exchanger helps to save more power than the other types of heat exchanger and the reason for that are low pumping power required, also because this technique mostly depends on the gravity, the device has a high heat transfer coefficient and easy to maintenance with this advantages the device also reduce power consumption and cost value.

Realistic constraints applied to the project:

Table: Realistic constraints

Constraints	Status	Page No.
Economic	Applied	5
Environmental	Applied	6
Sustainability	Applied	6
Manufacturability	Applied	6
Ethical	Applied	6
Health and Safety	Applied	6

Standards used in the project:

Table 2: Standards used in the project

Code of Standard:	**Name of the standard**
ASHRAE Standard 41.1-86	Standard method for temperature measurement
ASTM B75 / B75M - 11	Standard Specification for Seamless Copper Tube

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Nomenclature

$\dot{m}_{CP}$: mass flow rate of cooling path (kg/s)

$\dot{m}_{FF}$: mass flow rate of falling film (kg/s)

Γ : mass flow rate per unit length (kg/s.m)

D : diameter of tube (m)

l : length of tube (m)

n : number of test tube

A : area of test tube (m^2)

A_{total} : total area of tube (m^2)

k : thermal conductivity (W/m.K)

C_{PC} : specific heat of cooling path (kJ/kg.K)

C_P : specific heat of water outside test tube (kJ/kg.K)

μ : dynamic viscosity of water ($N.s/m^2$)

ρ : density of water (kg/m^3)

$T_{in, FF}$: falling film inlet temperature (C°)

$T_{out, FF}$: falling film outlet temperature (C°)

ΔT_{FF} : falling film temperature difference (C°)

$T_{in,CP}$: cooling path inlet temperature (C°)

$T_{out,CP}$: cooling path outlet temperature (C°)

ΔT_{CP} : cooling path temperature difference (C°)

Q_{FF}:total heat transfer rate (W/m^2)

Q_{CP} : total heat transfer rate (W/m^2)

U :overall heat transfer coefficient ($W/m^2.K$)

ΔT_{lm}: log mean temperature (C°)

Nu: Nusslet number

Re :Reynolds number

CHAPTER 1: PROBLEM DEFINITION

1.1 Project idea or problem

Maintenance is a major problem for most of heat exchangers. Heat exchanger that requires the least maintenance is preferred in many applications. The idea of project is to design a special type of heat exchanger, which requires less maintenance.

1.2 Situation Description

Heat exchanger problems are not always accompanied by obvious symptoms such as leaks or channel intermixing. Some problems are minor but progressive, causing higher energy consumption and performance variability. Dirt, deposits, scale and other fouling rob your plate-type heat exchangers of their design efficiency, risking damage to expensive equipment and unscheduled downtime for repairs. Heat exchanger maintenance is critical for controllability and energy efficiency. Typical problems include interior comfort complaints, off-grade product, escalating utility bills and related troubles. Methodical diagnostics will save time and prevent wasted effort. These should be outlined in your heat exchanger operations and maintenance manuals. The idea of this project is to design falling film heat exchanger that uses horizontal tubes to heat a liquid that falls on the outer tubes surface. This type of heat exchanger is characterized by the easy maintenance and the reason behind that is one pass-shell heat exchanger also this type of heat exchanger has low fouling because of the low temperature as seen inFigure 1- **1.**

Figure 1- 1:Fouling in a heat exchanger [1]

1.3 Revise Client Problem Statement

Based on the situation description, the idea of this project is to design a falling film heat exchanger that use horizontal tube to produce hot water for domestic uses and low fouling factor that is lead to low cost of maintenance as seen inFigure 1- **2**.

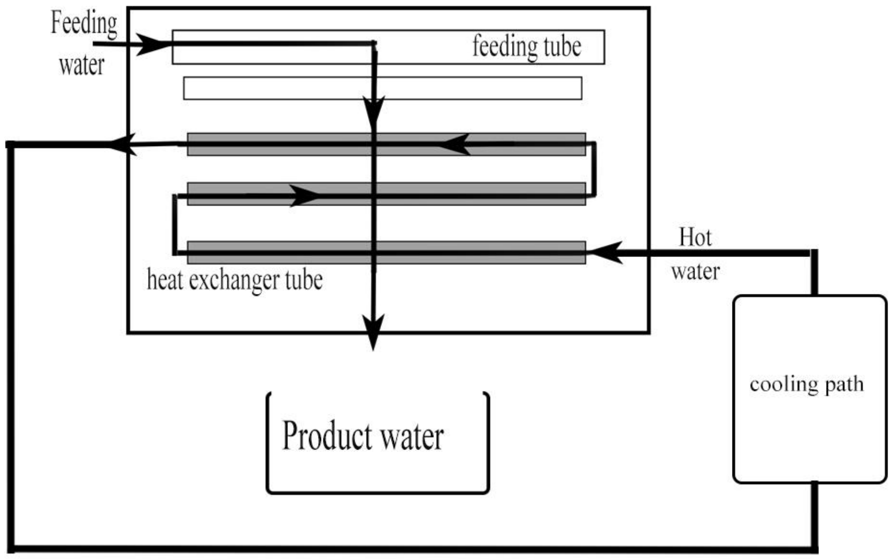


Figure 1- 2: Falling film in a heat exchanger

1.4 Need and opportunity

The demands of heat exchangers are increase in industrial and commercial market. The heat exchangers can be used in many applications such as air conditioning, food industry and domestic uses. There is many types of heat exchanger in the market for different applications but the main problem in these heat exchangers are the maintenance process and the cost therefore there is a good opportunity for the falling film heat exchanger in the commercial application specially the domestic uses.

1.5 Project Scoping

The main idea of this project is to design a heat exchanger by using falling film technique with horizontal tubes for domestic application: Therefore:

In scope:

- Design the heat exchanger box
- Optimize tubes arrangement of heat exchanger

Out scope:

- Cold water supply,
- Hot water supply.

1.6 Project objectives

The main objective of project is to design a small scale falling film heat exchanger to heat a fluidused in domestic and industrial applications. Another objective is to optimize the tube spacing and liquid flow rate influence on falling film formation. This objective is to increasethe heat transfer coefficient.

1.7 Design attributes of the objectives

The meaning of the word “design attributes” is the criteria or characteristics that the design should have. The designer should commit himself to good attributes. So if the attributes were good enough automatically the product will be more marketable, because the attributes are the base that the product will built on these are:

1) The artifact should be easy to maintenance.
2) The artifact shouldhave low maintenance cost
3) The artifactshould be marketable.
4) The artifactshould be reliable.
5) The design should be safe to use.
6) The design should be easy to use.

1.8 Objectives tree with metrics

Based on the objectives of the project and design attributes the objective tree will as:

- Objective’s attributes:

a) The artifact should be easy to maintenance:
    - ❖ Easy to assembling and dissection (1 hour for assembling if all parts is ready)
    - ❖ Few parts (max. 10 parts)

b) The artifact should have low maintenance cost:
    - ❖ Spare parts available (in the local market with affordable prices)

c) The artifact should be marketable
    - ❖ Not expensive (Max. SR 3000)
    - ❖ Low cost material (available materials in the local market)

d) The artifactshould be reliable and safe

- ❖ Safety standard and regulations applied (Occupational Safety and Health Standards (OSHA))
- ❖ Related ASTM Standard will be applied

Table 1- 1: Pairwise comparison chart

Goals	Easy to maintenance	Low maintenance cost	Marketable	Reliable	Safe	Easy to use.	Score
Easy to maintenance	…	1	1	0	1	1	4
Low maintenance cost	1	…	1	1	0	0	3
Marketable	1	0	…	0	0	1	2
Reliable	0	0	0	…	1	0	1
Safe	0	0	1	0	…	1	2
Easy to use.	1	0	0	0	1	…	2

1.9 Prioritizedlist of design attributes

- Easy to maintenance (4)
- Low maintenance cost(3)
- Marketable(2)
- Safe (2)
- Easy to use (2)
- Reliable(2)

1.10 Project customers and stakeholders

Stakeholders are persons or organizations who are actively involved in the project or whose interests may be positively or negatively affected by its performance or completion. They may be categorized as internal, external, or secondary, players, as business or non-business actors, as proponent or opponent, or as economic, social, environmental or technical. Table 1- **2** and Table 1- **3** in the next page are shown the definition of stakeholders.

Table 1- 2: Power-Interest matrix

		Level of Interest	
		Low	**High**
power	**low**	A- Mimimal Effort	B- Keep Informed
	high	C- Keep Satisfied	D- Key Player

Table 1- 3: Definition of stakeholders.

Symbol	Definition
A	Team members
B	Dr.Hani – Dr.Yasien- Dr.Nadem
C	LAP Engineers – Engineers who helped
D	MEP Department -ABET

The stakeholders was Classified into four categories

- **Internal Stakeholders** are accessible and easily and deal with them with a permanent presence in the project such us Team members, Dr.Hani, Dr. Yasien and Dr.Nadem.
- **External stakeholders** have to communicate indirectly, their own terms clear and specific as ABET.
- **Secondary players stakeholders** are need them at specific times as LAP Engineers - Engineers who helped.
- **Business stakeholders** need them in economic issues in the project as MEP department.

1.11 Realistic constraints

In this step we must limit the size of the design space by ignoring the unacceptable alternative.

a) Economic:

This project should not exceed 3,000 SR as a total production cost. The customer will bay 50 SR as a regular maintenance annual. The product need to development the electrical power input for decreasing the electrical cost. This development cost 350 SR.

b) Environmental:

Environment benign materials will be used.

c) Sustainability:

The artifact will be in the market with feasible services and maintenance available.

d) Manufacturability:

One advantage of this product it’s can be build in the lab department. The artifact that is going to be used must be manufactured locally. Also the heat exchanger materials are chosen from the available materials in the market.

e) Ethical:

The Code of Ethics of Saudi Council of Engineering (SCE) will be followed in the development or use of the artifact.

f) Healthy and safety:

It is required to use output water with safe conditions so that customer skins will not be harmfully affected. High-temperature water with temperature above 43 °C causes skin damage.In the safety constraints, the maximum allowable temperature to the customer does not exceed 43°C. This constraint is a very important one in our design, because when the water temperature becomes more than 43°C the human skin will be minor burned. So that is not acceptable product because safety is first.Safety standard and regulations will be applied (Occupational Safety and Health Standards (OSHA)).

1.12 Project other constraints

- The heated water should not exceed 43 ^{o}C
- Maximum flow rate of the cooling path is4 kg/min.
- Minimum flow rate of the falling film is1 kg/min.

1.13 Literature review

Heat exchanger is equipment that permits to transfer heat from a hot fluid to a cold one without any direct contact of fluids.They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, and sewage treatment.For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow through the exchanger. The exchanger's performance can also be affected by the addition of fins or corrugations in one or both directions, which increase surface area and may channel fluid, flow or induce turbulence. There are many deferent types of heat exchangers compared to falling film heat exchanger such as:

- **Double pipe heat exchangers** are the simplest exchangers used in industries. On one hand, these heat exchangers are cheap for both design and maintenance, making them a good choice for small industries. But on the other hand, low efficiency of them beside high space occupied for such exchangers in large scales.
- **Shell and tube heat exchangers** are typically used for high-pressure applications this is because the shell and tube heat exchangers are robust due to their shape.Using a small tube diameter makes the heat exchanger both economical and compact [2].
- **Plate heat exchangers** are composed of multiple, thin, slightly separated plates that have very large surface areas and fluid flow passages for heat transfer. This type of heat exchangers is used in HVAC and refrigeration applications.
- **Plate and fin heat exchangers** are usually made of aluminum alloys, which provide high heat transfer efficiency. The material enables the system to operate at a lower temperature and reduce the weight of the equipment. Plate and fin heat exchangers are mostly used for low temperature services such as natural gas, helium and oxygen liquefaction plants, air separation plants and transport industries such as motor and aircraft engines [2].

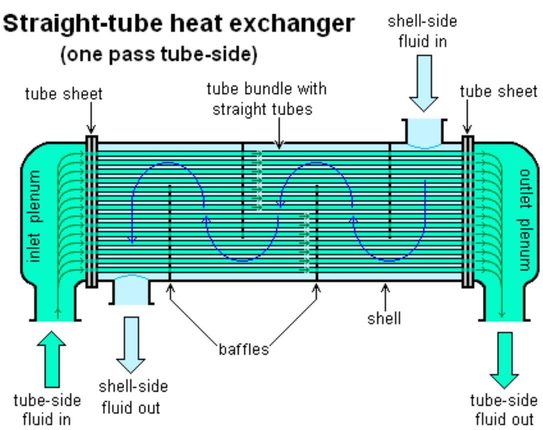


Figure 1- 3: Shell and tube heat exchanger[2]

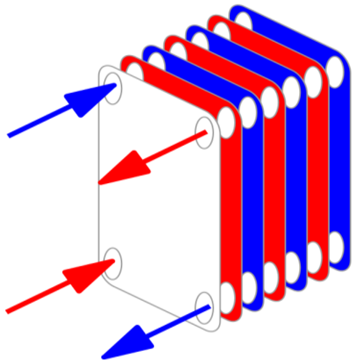


Figure 1- 4: Plate heat exchanger[2]

Falling film technique is used in much application, trying to find a manufacturers use this technique in heat exchanger is difficult. Most of manufacturers use falling film technique in evaporators and they are used many methods and ways to make this technique and manufacture it under specific client requirement. For the falling film evaporators and condensers used in the refrigeration industry, the flow pattern and its role in determining how the liquid falls from upper to lower tubes is important in determining the so-called inundation effect for applications in desalination and chemical processing, where sensible heat transfer is more important, the nature of the falling film flow has a direct impact on convective heat transfer.

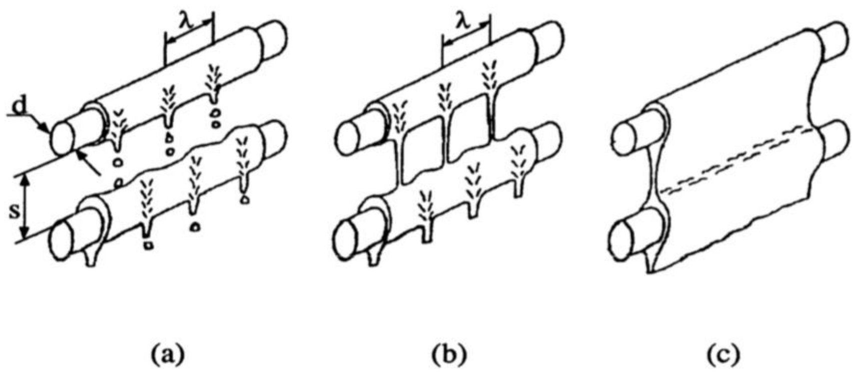


Figure 1- 5: (a) droplet mood, (b) jet mood, (c) sheet mode [3]

When a falling liquid film flows from a horizontal tube to another below it, the flow may take the form of a sheet, jets, or droplets; this characteristic of the flow is referred to as the falling-film mode. When the film flow rate is low, the liquid leaves the tube in the droplet mode. If the flow rate is increased, there is a transition from droplets to circular jets (droplet/jet transition).

CHAPTER 2: CONCEPTUAL DESIGN

2.1 Quality Function Deployment (QFD)

QFD is a methodology for defining the customer’s desires in the customer’s own voice, prioritizing these desires, translating them into engineering requirements, and establishing targets for meeting the requirements.QFD is documented in the form of a House of Quality. Figure 2- **1**shows the House of Quality for this project.

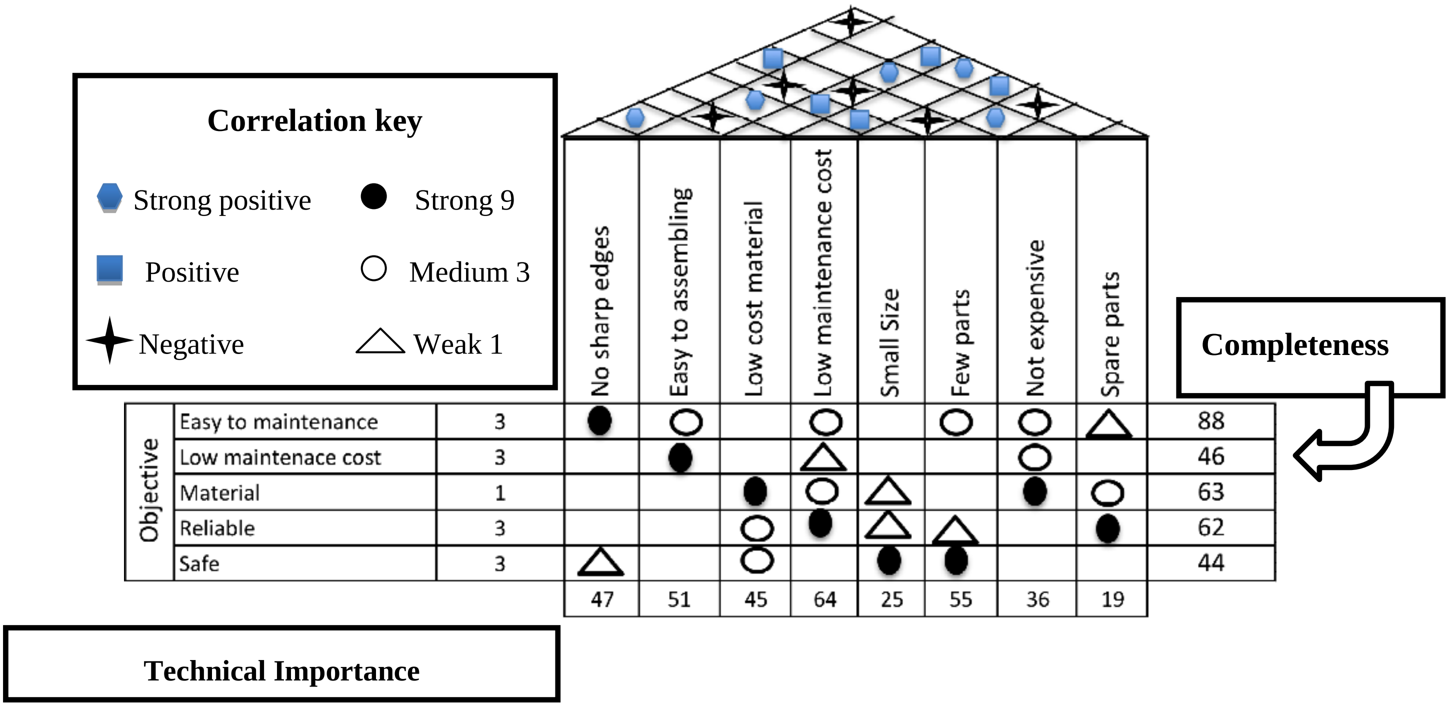


Figure 2- 1: House of Quality

2.2 Major Function

Designing function is about choosing the best alternative. A black box is one of the techniques that used in this assignment. Other technique used in this assignment is the transparent box. To show how each function works a Function-Tree mean technique has been used. Some other techniques used to get the best alternative.

2.3 Design Function

A falling film heat exchanger is about to design with vertical or horizontal tubes.

1) Horizontal

1.1 Tube marital
- 1.1.1 Titanium
- 1.1.2 Copper
- 1.1.3 Iron

1.2 Tube surface
- 1.2.1 Signal groove
- 1.2.2 Double groove
- 1.2.3 Smooth

1.3 Mode
- 1.3.1 Jet
- 1.3.2 Sheet jet
- 1.3.3 Droplet

1.4 Box material
- 1.4.1 Fiberglass
- 1.4.2 Iron
- 1.4.3 Reinforced plastic

2) Vertical

2.4 Transparent Box

Is a method of testing software that tests internal structures or workings of an application, as opposed to its functionalityIn transparent testing an internal perspective of the system, as well as programming skills, are required and used to design test cases [5]. The tester chooses inputs to exercise paths through the code and determine the appropriate outputs. As shown in Figure 2- **2**

Error! Reference source not found.

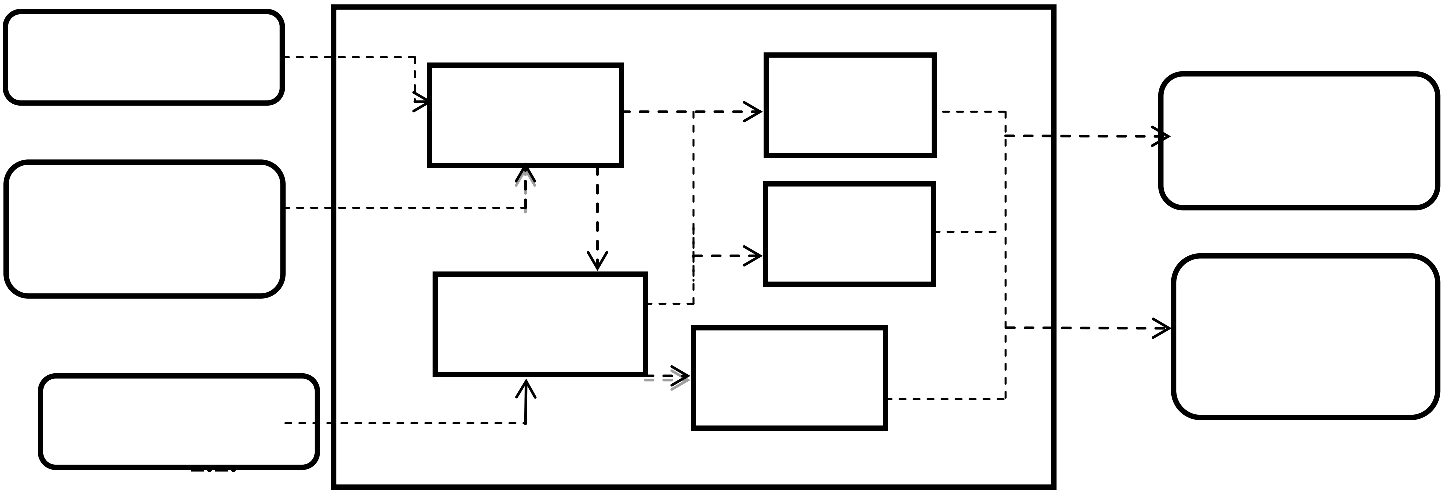


Figure 2- 2: Transparent box for falling film heat exchanger

2.5 Black Box

In science and engineering, a black box is a device, system or object which can be viewed solely in terms of its input, output and transfer characteristics without any knowledge of its internal workings [6] as shown in Figure 2- **3**

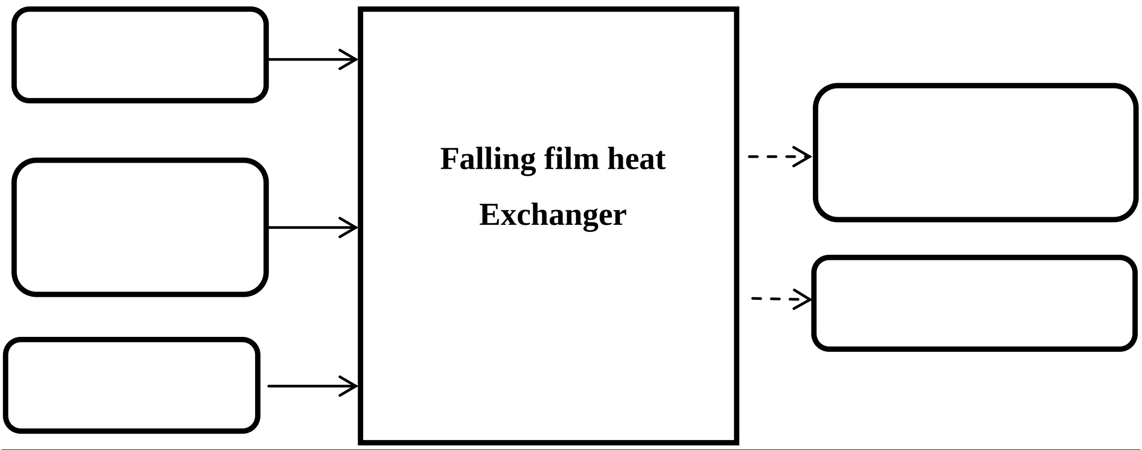


Figure 2- 3: Black box for falling film heat exchanger

2.6 Function-Mean Tree

Function–means tree is a method for functional decomposition and concept generation. At the top level main functions are identified. Under each function, a means (or solution element) is attached. Alternative solution elements can also be attached. Each means is in turn decomposed into functions with means attached to each of them. A well elaborated function means tree span a design space where all concepts under consideration are represented. Requirements can be attached to functions. Figure 2- **4**below show the Function and mean for falling film heat exchanger.

Error! Reference source not found.

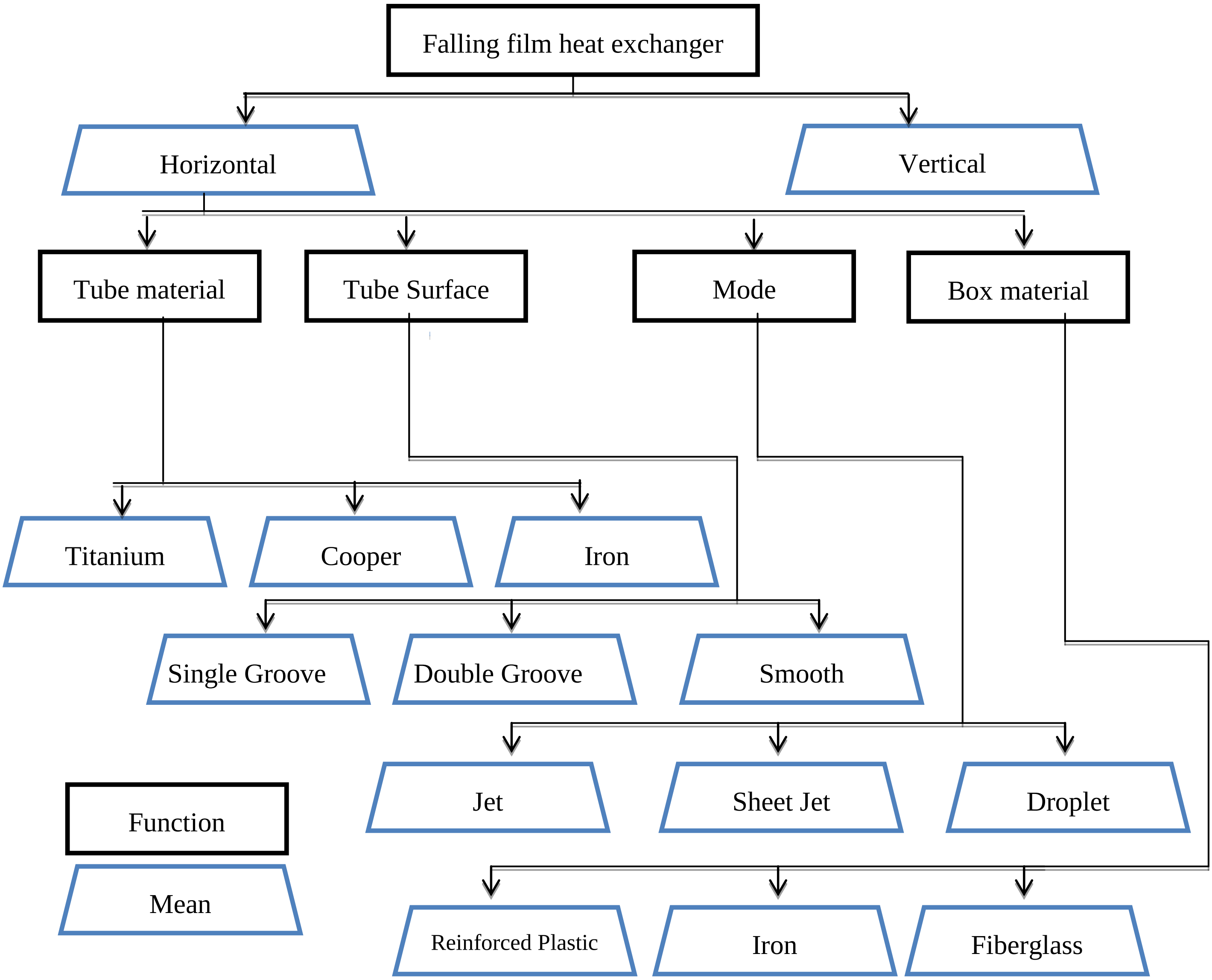


Figure 2- 4: Function-mean Tree

2.7 Morphological Chart

A morphological chart, also known as concept combination or function-means, is a tool for systematic combination of solutions to a design problem.

Table2- 1:Morphological chart for design alternative 1

Function	1	2	3	4
Type	Horizontal			
Tube material	Cooper	Iron	Titanium	
Tube surface	Smooth	Double groove	Single groove	
Mode	Drop	Jet	Jet-sheet	Sheet
Box marital	Iron	Reinforced plastic	Fiberglass	

Table2- 2: Morphological chart for design alternative 2

Function	1	2	3	4
Type	Horizontal			
Tube material	Cooper	Iron	Titanium	
Tube surface	Smooth	Double groove	Single groove	
Mode	Drop	Jet	Jet-sheet	Sheet
Box marital	Iron	Reinforced plastic	Fiberglass	

Table2- 3: Morphological chart for design alternative 3

Function	**1**	**2**	**3**	**4**
Type	Horizontal			
Tube material	Cooper	Iron	Titanium	
Tube surface	Smooth	Double groove	Single groove	
Mode	Drop	Jet	Jet-sheet	Sheet
Box marital	Iron	Reinforced plastic	Fiberglass	

Now we have four alternatives for dinging Falling Film Heat Exchanger. First one is horizontal with copper tube, Double drove surface tube surface, sheet jet mode and reinforced plastic as the box material. Second alternative is horizontal with iron tube, smooth surface tube surface, sheet jet mode and iron as the box material. Third one is horizontal with titanium tube, smooth surface tube surface, jet mode and fiberglass as the box material. 4th alternative is horizontal with copper tube, droplet surface tube surface, jet mode and reinforced plastic as the box material.

2.8 Pugh’s Method

Pug’s Method is a technique use to choose the best alternative, by evaluating each alternative. Figure 2- **5Error! Reference source not found.**Shows the Pugh’s Method for this project.

Pugh's Method					Alternatives		
#	Objective	Weight Status	Weight value		1	2	3
1	Easy to maintenance	Weight is Considered	4		-1	1	1
2	Low maintenance cost		3		-1	1	1
3	Marketable		2		-1	1	1
4	Reliable		1		-1	0	0
5	Safe		2		1	0	1
6	Easy to use.		2		1	-1	1
	Total Positive (+)				2	3	4
	Total Negative (-)				4	1	0
	Total score				-6	7	13

Figure 2- 5: Pugh’s method

CHAPTER 3: PROJECT MANAGEMENT

3.1 Structure

The structure for the project will show the role of each member as shown in below.

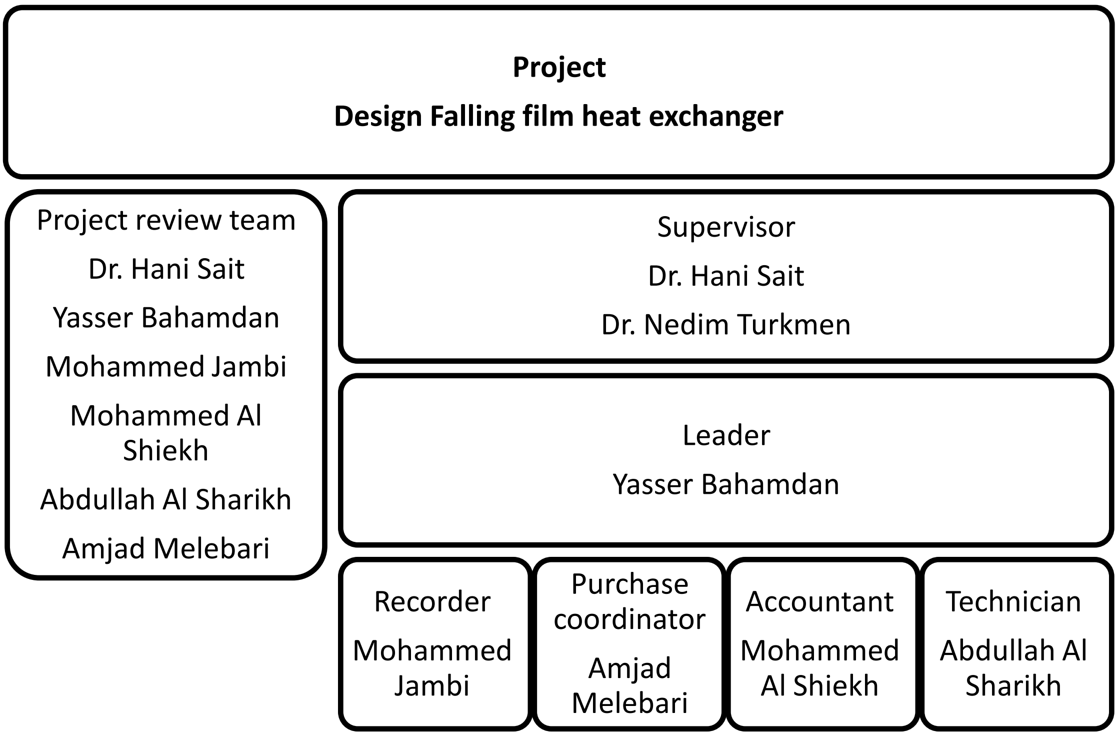


Figure 3- 1: Roles of members

3.2 Project Deliverables

The deliverables of the project is shown inTable 3- **1**.

Table 3- 1: Items of deliverables and its components

Item	Components	Description
Project technical report	• Project charter. • Final design. • Manufacturing and testing. • Technical drawings.	• Terms of reference made by team members and approved by customer, advisor, sponsor, Project manager and team members. • Complete calculations and simulation for selected solution. • Produce all parts and assembly depending on manufacturing process sheets and then test final product • Complete working drawings for each part and for the assembly.
Project presentations	• Project Charter presentation. • First Hand Design Presentation. • Final Design Presentation. • Final Presentation.	• Present what team made in project charter. • Present initial solution of problem. • Present and explain final design drawings and results. • Present all work in project, final product and testing results
Project Logbook	• Project Plan on Gantt chart. • Weekly project status report. • Meeting minutes. • Technical Report. • Presentations. • Draft work of the team Miscellaneous.	• Include Current week expanded and other sections suppressed. • Monitoring state of project weekly. • Keep team, adviser and customer meeting minutes. • Copy of technical report in logbook. • Material presented 6 slides in one paper. • Collection of all hand work of team member. Collection of any other thing related to the project

3.3 Work Breakdown Structure (WBS)

It is a deliverable oriented hierarchical decomposition of the work to be executed by the project team. And it is the key project that organizes the team's work into manageable sections. **Error! Reference source not found.**in the next page depicts the WBS with five levels defined.

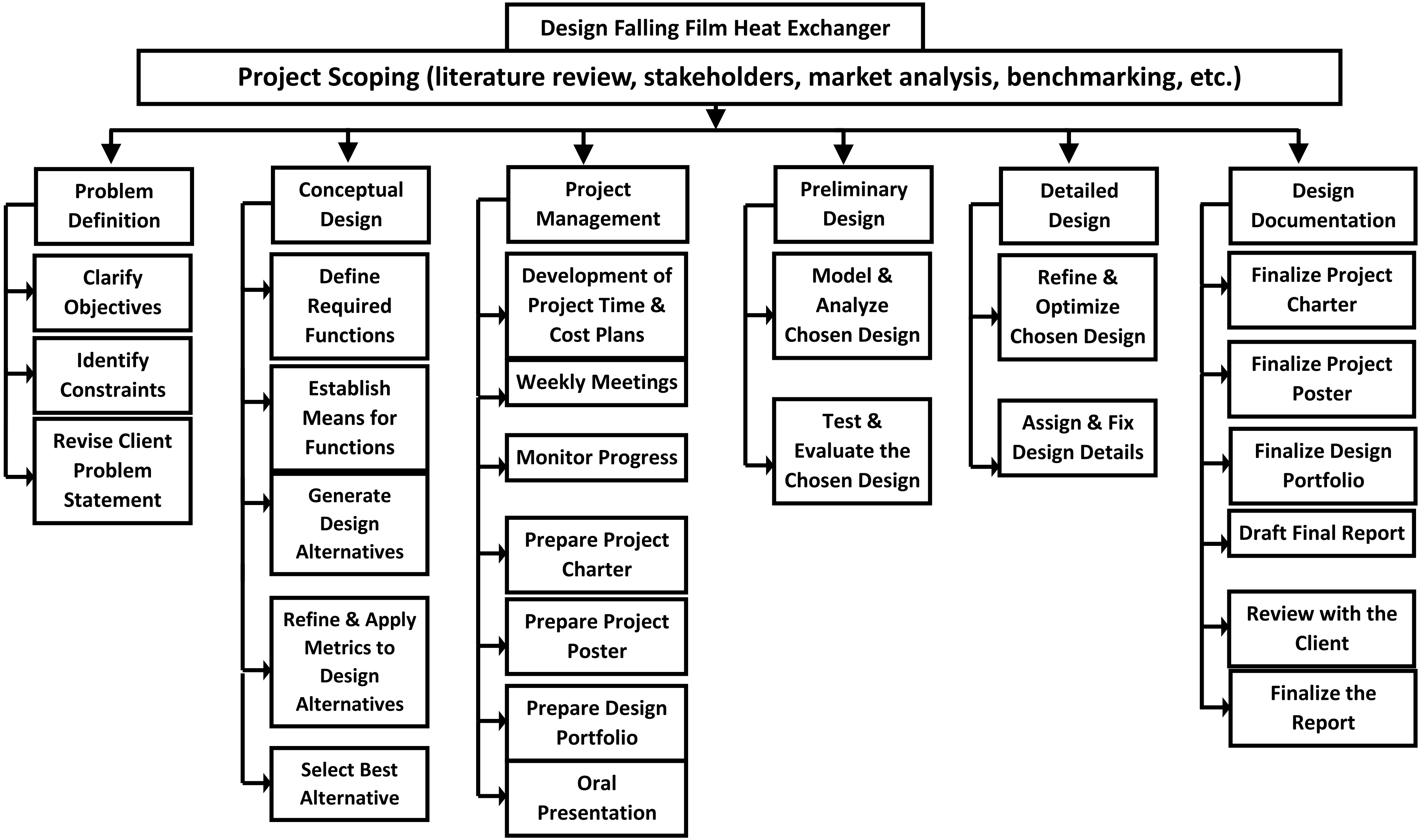


Figure 3- 2: Work Breakdown Structure (WBS)

3.4 Project Plan

In this section the approach of each subject regarding the project will be constructed, also the overall plan using Gantt chart technique will show the deadlines, financial plan and quality plan of the project will be organized.

3.4.1 Approach

Here we will describe the phases and approach for each element in the project as shown in Table 3- **2**.

Table 3- 2: Approach of phase

Phases	Approach
Initiation	The Goal Of This Phase Is To Build The Project. All Members Will Start To Do It By Collecting Information And Requirements.
Planning	Using MS Project Program For Project Plan And Actions.
Execution	The Team Will Start Alternatives Solution And Selection Design According To Requirements. Then, Start Analysis, Generating Alternatives, Manufacturing And Testing.

3.4.2 Overall Plan

The MS project was used to plan our project using Gantt chart technique step by step and its deadline as shown inFigure 3- **3**.

	Task Name	Duration	Start	Finish
1	Problem Definition	91 days	Sun 08-09-13	Fri 10-01-14
2	Clarify Objectives	90 days	Sun 08-09-13	Thu 09-01-14
3	Identify Constraints	7 days	Sun 22-09-13	Mon 30-09-13
4	Revise Client Problem Statement	81 days	Sun 22-09-13	Fri 10-01-14
5	Conceptual Design	7 days	Tue 24-09-13	Wed 02-10-13
6	Define Required Functions	7 days	Sun 29-09-13	Mon 07-10-13
7	Establish Means for Functions	7 days	Tue 01-10-13	Wed 09-10-13
8	Generate Design Alternatives	14 days	Tue 08-10-13	Fri 25-10-13
9	Refine & Apply Metrics to Design Alternatives	14 days	Tue 15-10-13	Fri 01-11-13
10	Select Best Alternative	7 days	Sun 20-10-13	Mon 28-10-13
11	Project Management	187 days	Sun 08-09-13	Mon 26-05-14
12	Development of Project Time & Cost Plans	24 days	Sun 03-11-13	Wed 04-12-13
13	Weekly Meetings	187 days	Sun 08-09-13	Sun 25-05-14
14	Monitor Progress	6 days	Mon 12-05-1	Mon 19-05-1
15	Prepare Project Poster	14 days	Tue 12-11-13	Fri 29-11-13
16	Prepare Project Charter	14 days	Tue 12-11-13	Fri 29-11-13
17	Prepare Design Portfolio	91 days	Sun 08-09-13	Fri 10-01-14
18	Oral Presentation	6 days	Mon 19-05-1	Mon 26-05-1
19	Preliminary Design	6 days	Tue 01-04-14	Tue 08-04-14
20	Model & Analyze Chosen Design	6 days	Tue 08-04-14	Tue 15-04-14
21	Test & Evaluate the Chosen Design	6 days	Tue 15-04-14	Tue 22-04-14
22	Detailed Design	4 days	Tue 22-04-14	Fri 25-04-14
23	Refine & Optimize Chosen Design	2 days	Fri 25-04-14	Mon 28-04-14
24	Assign & Fix Design Detai	16 days	Mon 28-04-14	Mon 19-05-14
25	Design Documentation	97 days	Fri 10-01-14	Mon 26-05-14
26	Finalize Project Charter	6 days	Mon 19-05-14	Sun 25-05-14
27	Finalize Design Portfolio	97 days	Fri 10-01-14	Sun 25-05-14
28	Draft Final Report	5 days	Sun 25-05-14	Thu 29-05-14
29	Review with the Client	4 days	Wed 28-05-14	Mon 02-06-14
30	Finalize the Report	19 days	Mon 02-06-14	Thu 26-06-14

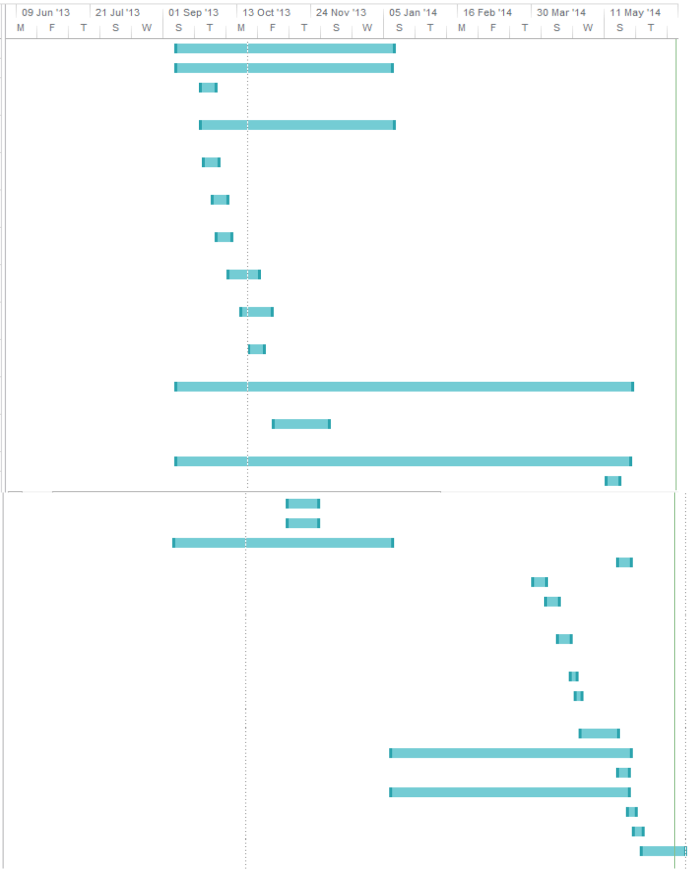


Figure 3- 3: Overall planning by Gantt chart

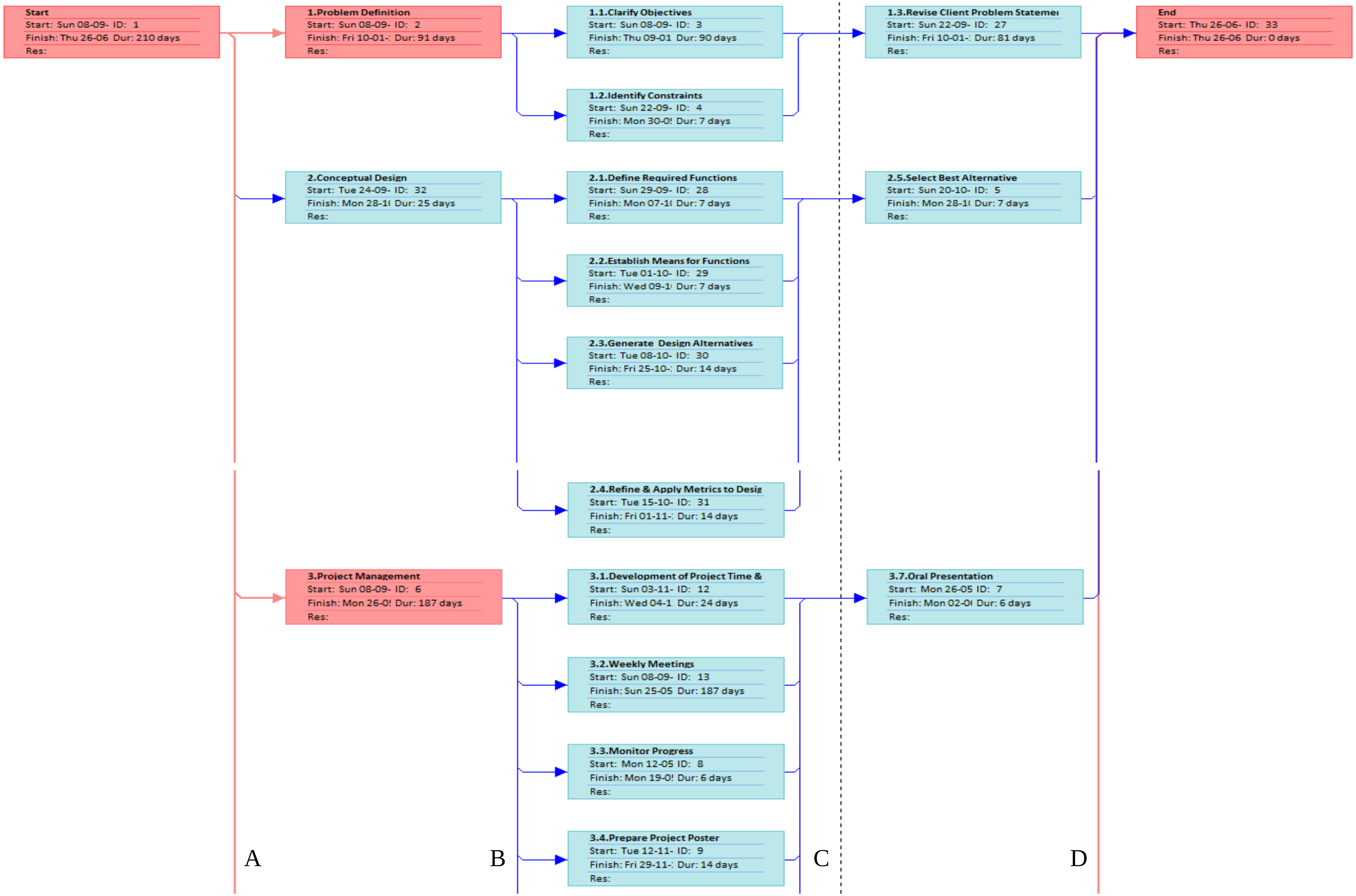
3.4.3 Milestone

A 'milestone' is a significant event or stage to be completed. The major project milestones and the required delivery dates have been listed as shown in Table 3- **3**.

Table 3- 3: Milestones of phases

Milestone	Date	Description
Submit senior project proposal form	5-Sep-2013	Present the proposal to the supervisor
senior project proposal approval	12-Sep-2013	Get the approval from the supervisor
Modifications	13-Jan-2014	Submit corrections for all mistakes found in assignments
Submit the design folder	13-Jan-2014	Submit the design folder
Final Presentation	13-Jan-2014	Present the Project with the poster to the supervisor

3.4.4 Activity On node diagram (AON)



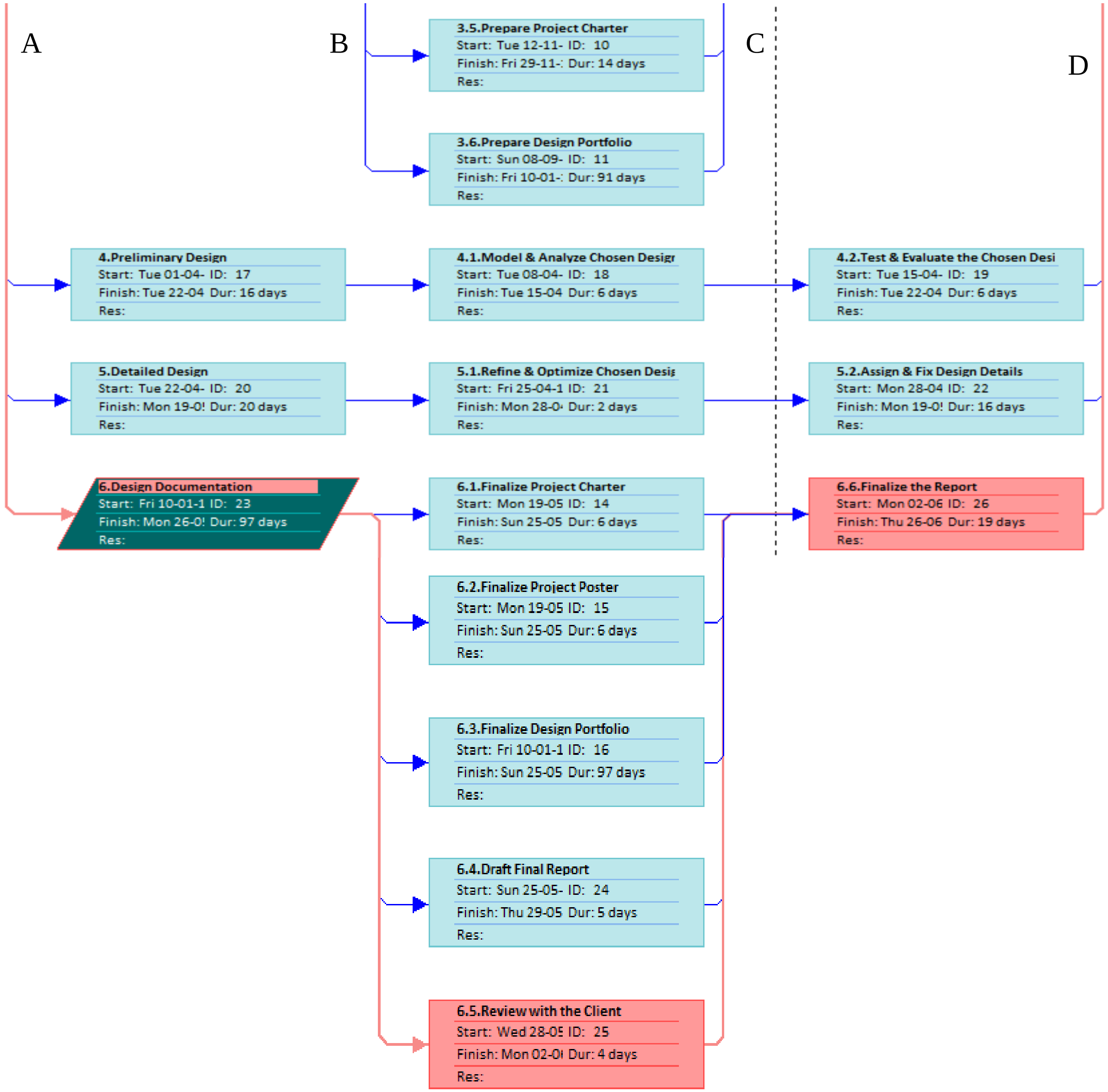


Figure3- 1: Activity On Node Diagram (AON)

3.4.5 Resource Plan

Duration and effort required for each project members have been summarized. From Gantt chart, the estimate date of each member from 1-Sep-2013 to 13-Jan-2014. The effort is estimated by each member is shown in Table 3- **4**.

Table 3- 4: Start and end date of each member and their effort

Role	Start date	End date	Effort
Team members	1-Sep-2013	13-Jan-2014	90%
Supervisor assistance	1-Sep-2013	12-Jan-2014	40%

3.5 Project Considerations

Risks: The expected risks that could occur and obstruct the progress of the design and manufacturing. The level risks impact on the project were determined as well as the actions must be taken for each risk as shown in Table 3- **5**.

Table 3- 5:Risks

Description	Likelihood	Impact	Mitigating Actions
Water contact with electricity	Low	High	Make sure of the sealing and keep far as possible from any electricity.

Issues: Clarifying the issues that already exist and the ones that can affect the work during project process. Table 3- **6**

Table 3- 6:Issues and the resolution actions

Description	Priority	Resolution Actions
Facing Exams During The Semester	High	Cooperation First And Then Dividing The Tasks Between Team Members

3.5.2 Assumptions

- All appropriate resources that help the project are available whether they are people books or Information from the internet.
- Prices of raw materials will remain constant during project implementation.

3.6 Responsibilities

3.6.1 Linear Responsibility Chart (LRC)

It is a template lists the typical tasks involved in building a project according to its phase or stage. Each entry recommends who should take the lead and who else should be providing significant support for each task [7]. Table 3- **7**shows the linear responsibility chart of the project.

Table 3- 7: Linear responsibility chart (LRC)

LRC	Member 1	Member 2	Member 3	Member 4	Member 5	Advisor
1.0 Problem statement	1					
1.1 Clarify objectives	1	2		2		5
1.2 Identify constraints	2	1			2	5
1.3Revise client's statements	1		2		2	
2.0 Conceptual design			2	2	1	5
2.1 Establish functions			1	2	2	
2.2 Establish requirements	2	2	2	1	2	3
2.3 Establish means for functions	2	1				
3.0 Generate design alternatives	1	2			2	
3.1 Refine and apply metrics	1		2	2		5
3.2 Choose a design		1			2	3
4.0 Preliminary design	2		1	2		
4.2 Test & evaluate the chosen design	1	2			2	
5.0 Detailed design		1	2		2	3
5.1 Refine & optimize chosen design	1		2	2	2	
5.2 Assign & fix design details			2	1		5
6.0 Design documentation		2			1	
6.1 Draft final report	1		2	2		
6.1 Review with the client	1	2				
6.2 Finalize reports	2	2			1	5
7.0 Project management	2	2	1			5
7.1 Development of project	2	2	1	2	2	3

LRC	Member 1	Member 2	Member 3	Member 4	Member 5	Advisor
time & costs plans						
7.2 Weekly meetings	2	1	2	2	5	5
7.3 Monitor progress	1	2	2	2	2	1

3.7 Financial Plan

All the values in the next table are Estimation of the primary and expected cost as shown in Table 3- **8**.

Table 3- 8: Financial plan of the project

Labor fees	
Labor cost per hour (1 member)	5.20 SR
Team members	6
Total hours per week	20
Total weeks	39
Total labor cost	24,336 SR

3.8 Quality Plan

The quality plan is divided into five processes in our project .each process is described in detail as shown Table 3- **9**.

Table 3- 9: Description of each process

Process	**Description**
Change Management	Design The Project To Be Easy, Flexible And Adjustable For Any Changes.
Risk Management	The Team Predictions In Many Areas. Backup Plans Are Ready To Reduce The Effects Of Risks.
Issue Management	An Issue That Delays The Project Will Be Focused On And Solutions Will Be Applied As Soon As Possible.
Financial Management	A Member Of The Team Will Be Responsible For The Income And The Outcome From The Deposit.
Project Communications	The Teammates Will Communicate With Each Other Through Meetings, Phones And E-Mail.

CHAPTER 4: DESIGN METHODOLOGY

4.1 Introduction

A test box has been built to investigate the problem, it consists of the test section, and the test section consisted of feed tubes, test tubes and funnel. All the tubes are made of copper, which has a high thermal conductivity. The feed tube is setup above the test section, its height is 300 mm the length is 400 mm and the width is 100mm, diameter holes were drilled 2 mm apart from each other, providing26 holes. The feed tube has inside and outside diameters of 12.7 mm and 10 mm. It receives liquid from a cooling path. Three test tubes configured above each other with diameter of 12.7 mm are placed at a pitch of 130 mm under the feed tubes. They were all held by the supporting box, which was made of neon transparent. The cooling path gave a capability of adjusting the temperature to keep it constant. It was used to supply hot water inside the test tubes. A constant temperature tap water provides pure water to the outside of the test tubes with different flow rate. Outlet temperature and flow rate of water, inside and outside the test tubes were recorded. Surface temperature was measured for one tube. Data acquired was used for temperature measurement.

4.2 Scope and Limitations of the work

This work aims to analyze the heat transfer characteristics and temperature distribution of specific type of a falling film heat exchanger with horizontal feed tube. The analysis is limited by the manufacturing and fabricated structures of the test box. The tubes spacing is changeable and the tubes are connected in series. The type of the used feeding tube also limits the falling film flow. The low thickness of the tube, make it difficult to embed the thermocouples in the surface.

4.3 Measuring Techniques

The temperatures of the heated fluid inside the tube and water falling film were measured by using thermocouples type K. They are fixed in the tubes passageway. The flow rate of the heated fluid and the water falling film was measured by using calibrated flow meters.

4.4 Governing equations

Considering hot fluid inside tube to heat another fluid outside the tube. The thermal resistance consists of inside convective heat transfer and outside convective heat transfer.

Consider a hollow grooved cylinder with inner and outer surfaces are being exposed to fluids at different temperatures. The heat transfer rate in radial direction using Fourier's law of heat conduction is[8]:

$$Q = \frac{2\,\pi\, l\, k(T_{s,1} - T_{s,2})}{\ln(\frac{r_2}{r_1})} \qquad (1.1)$$

From this equation it is evident that for radial conduction in hollow cylinders, the thermal resistance would be[9]:

$$R_{t,cond} = \frac{\ln(\frac{r_2}{r_1})}{2\,\pi\, l\, k} \qquad (1.2)$$

In this case the heat transfer is carried out as that composite cylinder. The heat transfer may be expressed as shown in the following Figure 4- **1**

Figure 4- 1 Thermal resistance for the cylinder.

$$q_r = \frac{1}{h_1 2\,\pi\, r_{1\,l}} + \frac{\ln(\frac{r_2}{r_1})}{2\,\pi\, k\, l} + \frac{1}{h_2 2\,\pi\, r_2\, l} \qquad (1.3)$$

The flow in a circular tube is either laminar or turbulent depending on the value of Reynolds number. The Reynolds number for a flow in a circular tube is defined as [10]:

$$Re = \frac{\rho\, u_m D}{\mu} \qquad (1.4)$$

Where u_m is the mean fluid velocity over the cross section and D is the wetted perimeter. In a fully developed flow, the critical Reynolds number corresponding to the beginning of turbulence is:

$$Re_{D,c} \approx 2300 \qquad (1.5)$$

The mean fluid velocity is defined such that, when multiplied by the fluid density and the cross sectional area of the tube A_c, it provides the mass flow rate $\dot{m}$ throughout the tube[11].

$$\dot{m} = \rho\, u_m A_c \qquad (1.6)$$

For constant surface temperature condition, average convection coefficient is given as:

For laminar flow Re $\leq$ 2300

$$Nu = 1.86\left(\frac{Re\ Pr}{l/D}\right)^{1/3}\left(\frac{\mu}{\mu_s}\right)^{0.14} \qquad (1.7)$$

Where this equation can be applied for the following conditions:

Surface temperature T_s is constant

$0.48 < Pr < 16700$

$$0.0044 < \left(\frac{\mu}{\mu_s}\right) < 9.75$$

For turbulent flow:

$$Nu = 0.023\, Re^{0.8}\, Pr^{0.3} \qquad (1.8)$$

Where the ranges are:

$0.7 \leq Pr \leq 160$

$Re \geq 10{,}000$

$$\frac{l}{D} \geq 10$$

All properties should be evaluated at the average outlet and inlet temperature T except μ_s.

$$T = \frac{T_{in} + T_{out}}{2} \qquad (1.9)$$

Then:

$$h = \frac{Nu\ k}{D} \qquad (1.10)$$

Note: equation (1.8) can be used as approximation at a smaller Reynolds number than 10,000.

Equations for sensible heat transfer in a falling film are used to approximate the outside heat transfer coefficient, and these are the equations:

For sheet mode[12]:

$$Nu = 2.194\ Re_f^{\ 0.28} Pr^{\ 0.14} Ar^{\ -\ 0.20}\ (s/d)^{\ 0.07} \quad (1.11)$$

For jet mode[13]:

$$Nu = 1.378\ Re_f^{\ 0.42} Pr^{\ 0.26} Ar^{\ -\ 0.23}\ (s/d)^{\ 0.08} \quad (1.12)$$

For droplet mode[14]:

$$Nu = 0.113\ Re_f^{\ 0.85} Pr^{\ 0.85} Ar^{\ -\ 0.27}\ (s/d)^{\ 0.04} \quad (1.13)$$

The liquid properties were evaluated at film temperature T_f.

Where:

Nu: modified Nusselt number = $(\frac{\nu^2}{g})^{1/3}\frac{h}{k}$ (1.14)

Re_f: film Reynolds number = $2\ \Gamma/\mu$ (1.15)

Pr: Prandtle number = $\frac{C_p\ \mu}{k}$ (1.16)

Ar: Archimedes number based on tube diameter = $\frac{d^3 g}{\nu^2}$ (1.17)

CHAPTER 5: THERMAL SIZING OF FALLING FILM HEAT EXCHANGER

5.1 Introduction

Based on the lap experiment the team found the falling film heat exchanger is an effective heat exchanger that can be use in many applications. Cooling path is used as a heat source of water for the failing film heat exchanger. Copper tubes are used as a heat exchanger tube. Feeding water tube is fixed at the top of the heat exchanger box. Hot water exit from cooling path and enter the heat exchanger tube at the bottom of falling film heat exchanger box and leave it at the top back to cooling path. Three tubes are arranged above each other with double groove surface to heat the feeding water. Feeding water enter the falling film heat exchanger from the top via small holes inside the feeding tube. The product water is directly out the falling film heat exchanger from the bottom. Figure 5- **1**Show the circuit of falling film heat exchanger.

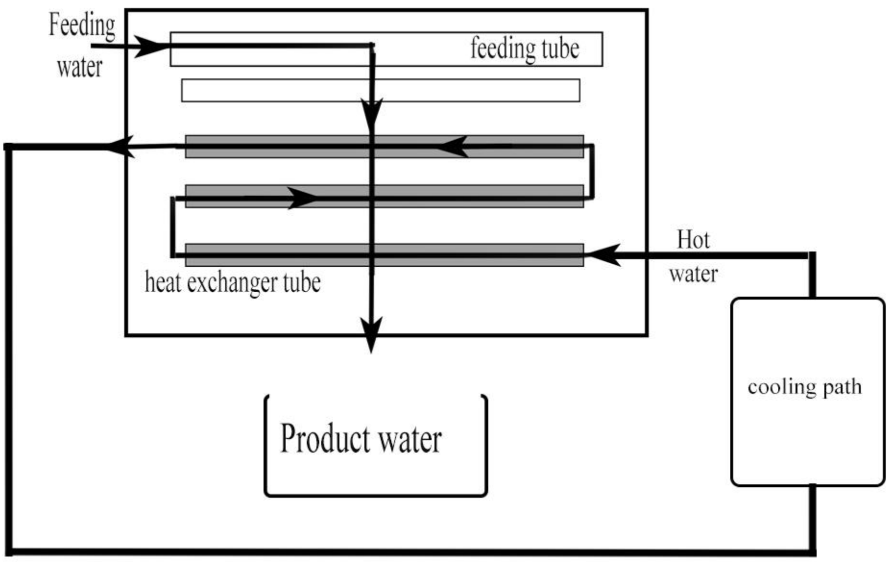


Figure 5- 1: The circuit of falling film heat exchange

5.2 Main technical and operation data

The average quantity of domestic water is 40 -30 lit/day in Saudi Arabia [4].The following information includes the main technical specifications and operating data:

Feeding water tube diameter = 12.7 mm

Heat exchanger tube diameter = 12.7 mm

Heat exchanger tube length = 135 mm

Number of heat exchanger tube = 3

Total area of heat exchanger tube (A_{dg}) = 0.041 m^2

Inlet temperature of hot water ($T_{cp,i)}$ = 80° C

Feed water mas flow rate (m_{ff}) = 0.043 kg/s

Hot water mass flow rate (m_{cp}) = 0.054 kg/s

5.3 Heat transfer rate for falling film

The sensible heat, Q_{ff}, of falling film is given by [15]:

$$Q_{ff} = m_{ff}Cp\ (T_{ff,o} - T_{ff,i})$$

Where m_{ff} = 0.0087 kg/s is the mass flow rate of feeding water, Cp = 4182 j/kg.k, $T_{ff,o}$ = 49.8 °C is the falling film temperature at the outlet and $T_{ff,I}$ = 22.7 °C is the falling film temperature at the inlet. The Q_{ff} =985.99 w for the drop mode in double groove surface.

5.4 Heat transfer rate for cooling path

The sensible heat, Q_{cp}, of cooling path is given by:

$$Q_{cp} = m_{cp}Cp\ (T_{cp,i} - T_{cp,o})$$

Where m_{cp} = 0.054 kg/s is the mass flow rate of feeding water, Cp = 4195 j/kg.k, $T_{cp,o}$ = 77 °C is the cooling path temperature at the outlet and $T_{cp,i}$ = 80 °C is the cooling path temperature at the inlet. The Q_{cp} = 679.59 w for the drop mode in double groove surface.

5.5 Heat transfer rate ratio

The heat transfer rate ratio is given by:

$$Q_{ff} / Q_{cp}$$

Where Q_{ff} = 985.99 w is the heat transfer rate of falling film and Q_{cp} =679.59 w is the heat transfer rate of cooling path. The heat transfer ratio Q_{ff} / Q_{cp} = 1.46

5.6 Overall heat transfer of falling film

The overall heat transfer of falling film is given by[16]:

$$U = \frac{Q_{ff}}{A_{dg} * \Delta T_{lm}}$$

Where

$$\Delta T_{lm} = \frac{(T_{cp,o} - T_{ff,i}) - (T_{cp,i} - T_{ff,o})}{ln \frac{(T_{cp,o} - T_{ff,i})}{(T_{cp,i} - T_{ff,o})}}$$

ΔT_{lm}= 41.1°C, Q_{ff} = 985.99 w is the heat transfer rate of falling film and A_{dg}=0.0177 m^2 is total area of double groove surface. U= 1351.07 W/m^2. K is the overall heat transfer of falling film for drop mode.

5.7 Nusselt number of falling film

Nusselt number of falling film given by [17]:

$$Nu = \frac{U \text{ x } D}{k}$$

Where U = 1351.07 W/m^2. K is the overall heat transfer, D= 0.0127m is the tube diameter and k = 0.64W/m.K is the thermal conductivity of falling film. Nu= 26.81 for the falling film.

5.8 Reynolds number of falling film

Reynolds number of falling film is given by [18]:

$$Re = \frac{2 \text{ x } \Gamma}{\mu}$$

Where Γ= 0.0644 kg/s.m is the mass flow rate per unit length and μ= 0.000577 N.s/m^2 is the dynamic viscosity of falling film. Re = 223.377 for the falling film at drop mode.

CHAPTER 6: DESIGN OPTIMAZITION

6.1 Introduction

This chapter presents the design optimization of falling film heat exchanger. Based on the experiment the mode of falling film is determent. Falling film heat exchanger has five different mode drop, drop-jet, jet, jet-sheet and sheet each mode give a different outlet temperature. Based on project constraint the outlet temperature dose not exceeds 43 °C for domestic uses.

6.2 Selecting falling film mode

Based on tow main things the falling film mode well be determined the outlet temperature and the water flow rate. Three modes are achieved the project constraint jet, jet-sheet and sheet as shown in Table 6- **1**

Table 6- 1: Results of double groove surface

Mode	DROP	DROP-JET	JET	JET-SHEET	SHEET
flow rate of cooling path (kg/s)	0.054	0.054	0.054	0.054	0.054
flow rate of falling film (kg/s)	0.0087	0.012	0.02	0.036	0.042
Γ	0.064	0.088	0.148	0.266	0.31
diameter of tube (m)	0.0127	0.0127	0.0127	0.0127	0.0127
Length of tube (m)	0.135	0.135	0.135	0.135	0.135
number of test tube	3	3	3	3	3
Area of test tube (m2)	0.0059	0.0059	0.0059	0.0059	0.0059
total Area of test tube (m2)	0.0177	0.0177	0.0177	0.0177	0.0177
thermal condetivety (w/m.k)	0.64	0.634	0.628	0.623	0.62
cp Cooling path (j/kg.k)	4195	4195	4195	4195	4195
Cp (j/kg.k)	4182	4179	4178	4178	4178.5
μ (N.s/m2)	0.000577	0.000631	0.000695	0.000739	0.000769
ρ (kg/m3)	988	990.2	993.74	994.46	994.98
inlet FF temperature (C)	22.7	22.7	22.7	22.7	22.7
OutLet FF temperature(C)	49.8	43.7	36	34	32.5
ΔTff ©	27.1	21	13.3	11.3	9.8
inlet tube temperature cp (C)	80	80	80	80	80
OutLet tube temperature cp (C)	77	74	71	77	74
ΔTcp	3	6	9	3	6
total rate heat transfer *Qff (W)*	986	1053.11	1111.34	1699.61	1719.87
total rate heat transfer *Qcp (W)*	679.59	1359.18	2038.77	679.59	1359.18
Qff/Qcp	1.45	0.774	0.545	2.5	1.265
overall heat transfer *U (W/m2.k)*	1351.06	1366.83	1356.47	1912.01	1960.65
ΔT	41.078	43.36	46.11	50.03	49.37
Nu	26.81	27.37	27.43	38.97	40.16
Re	223.37	281.73	426.32	721.69	809.13

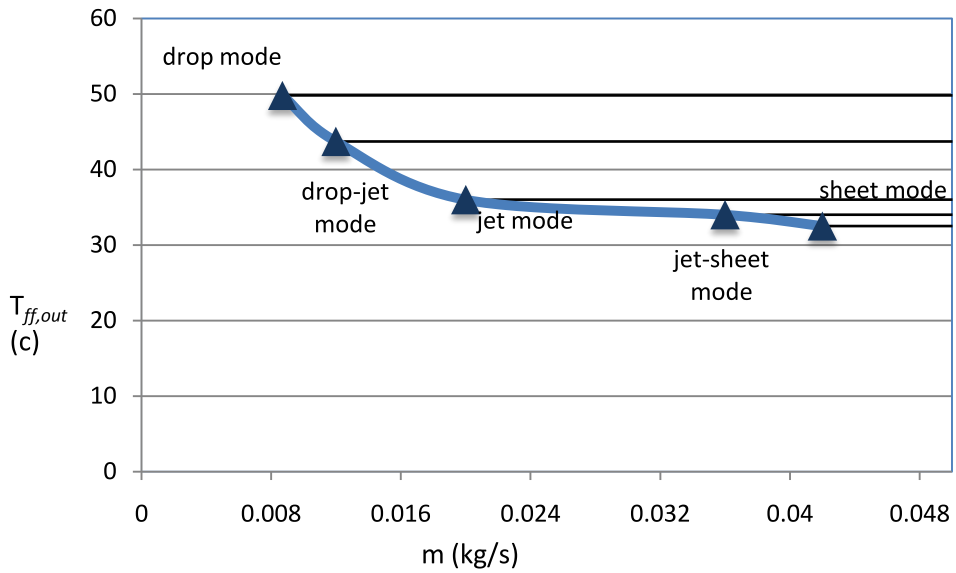


Figure 6- 1: Relation between $T_{ff.out}$ and flow rate

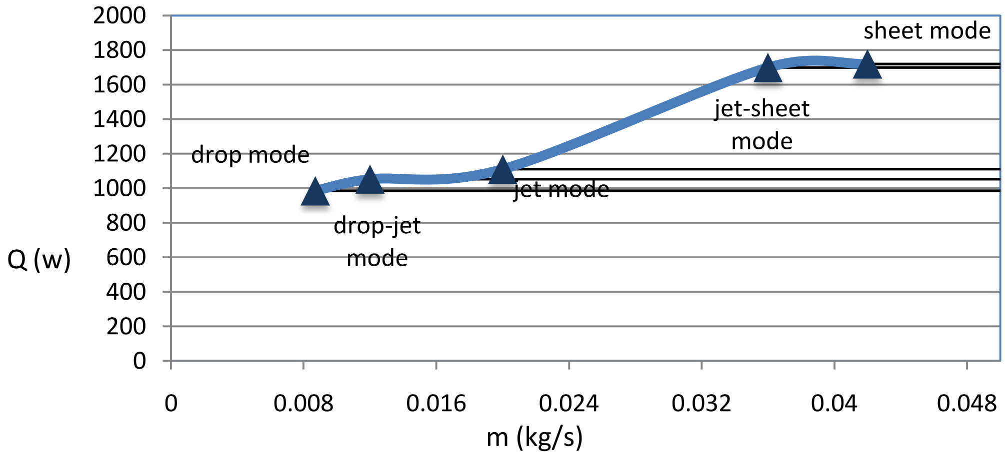


Figure 6- 2: Relation between Q and water flow rate

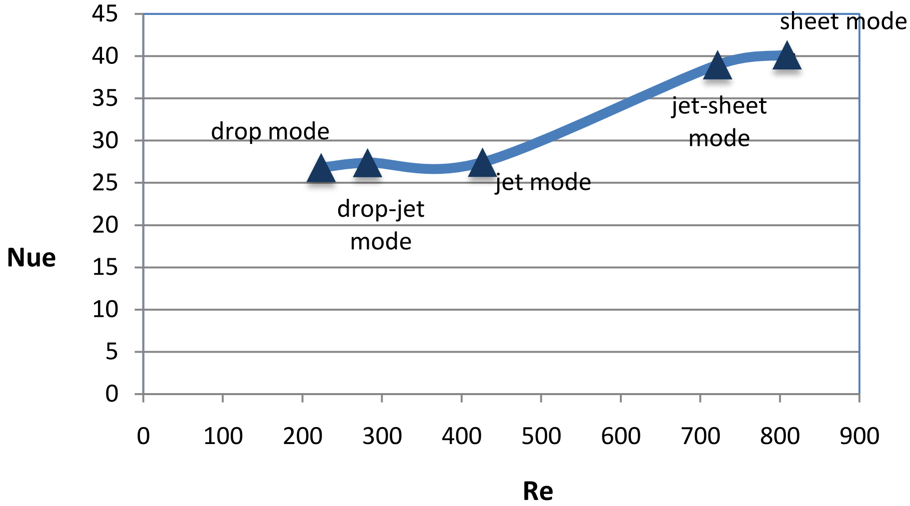


Figure 6- 3: Relation between Nue and Re

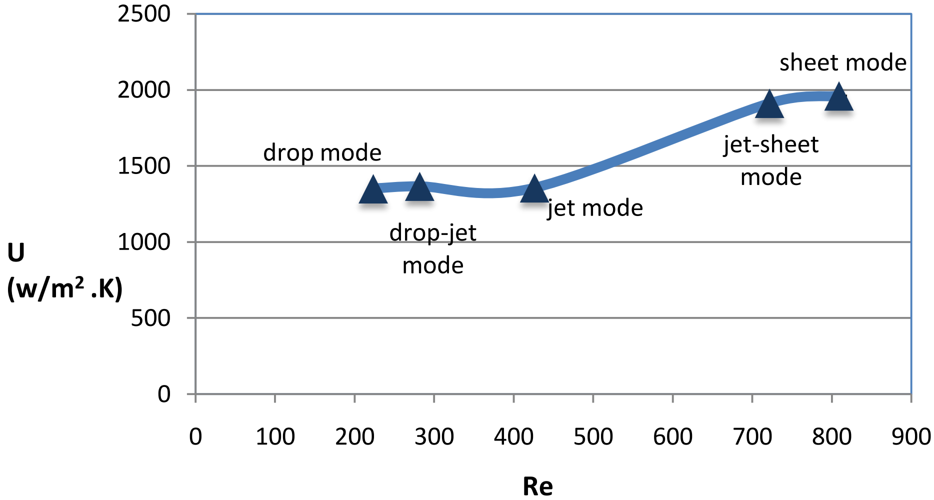


Figure 6- 4: Relation between U and R

CHAPTER 7: EXPERAMNITAL SETUP

7.1 Introduction

In this project a falling film heat exchange is about to design, with a specific condition of falling. This project divided into series chapters, this chapter supposes to explain how to manufacture this prototype of heat exchange. In order to reach the best design, several techniques have been used. Such as brine storming, Linear Responsibility Chart and other technique are applied. Then to selecting the best alternative we use Morphological Chart and Pugh's method.

7.2 Experimental methodology

The test box is designed and fabricated to increase the water temperature. A cooling path is used to produces high temperature fluid. In the beginning the water will comes from tap water with constant temperature. Then it will collect in the feed tube to start forming the sheet jet. In the meantime the cooling path will heat up the internal tubes, by pumping a high temperature fluid inside those tubes. Then a falling film will form to transfer heat between the tubes surface and water. Finally the water will collect in the tank.

7.3 Design setup

7.3.1 Design properties

For good results we chose a copper tube for the internal horizontal tubes, which we name it a test tube, fiberglass as the box material and double groove for the internal tubes surface. After studying the falling form, we decide to set the falling as a sheet jet.

7.3.2 Workshop

Now the internal tube surface was smooth so we went to the workshop to get double groove surface. Then we cut A 8 cm tube into two half to use it as the feed tube, this tube works as a water supply.

Figure 7- 1: part of the design

7.3.3 Feed water

To control the water feed, a group of holes with different diameters made by drilling the feed tube. Those holes separate from each other. Each group can fill separate or together.

For the sake of fix all parts together we used joints, glow and special channel. Then we stick a measurement tool to the main bar so we can estimate the pitch between tubes. In order to get an organized sheet jet, a smooth tube has been fix after the first holder.

7.3.4 Test tube

For more accurate reading, the test tubes set as a movable tubes. To ensure that the tubes remain in their place, we use belts. A set of two belts from each side has been fixed into the main bar.

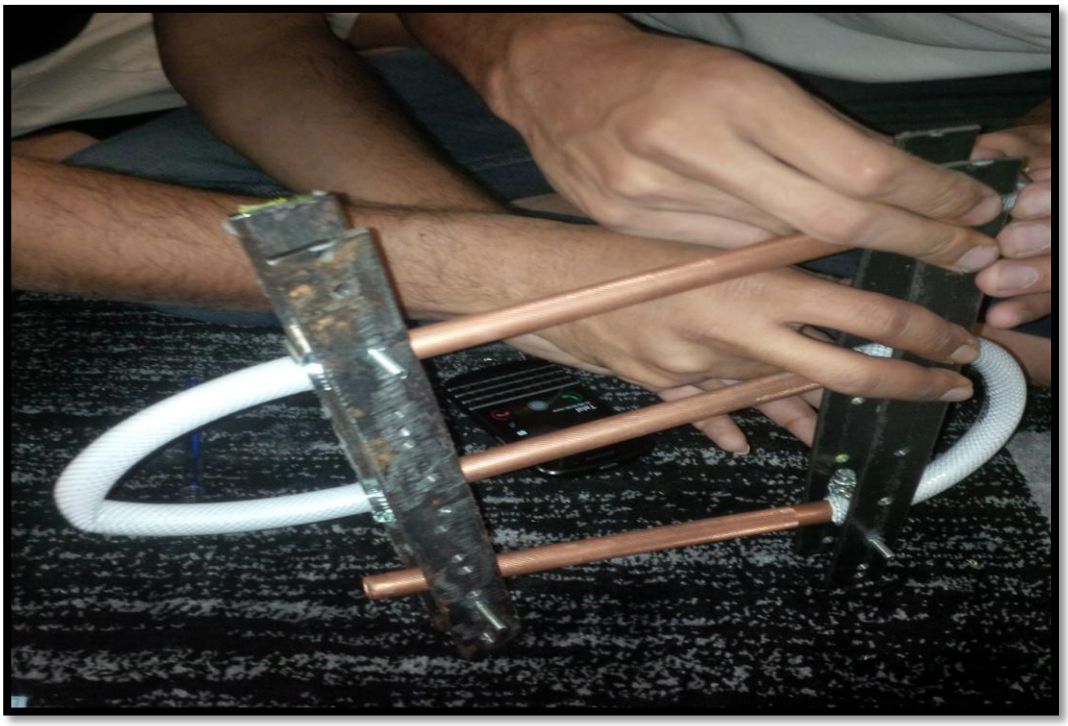


Figure 7- 2:Ddouble groove tube

7.3.5 Heating loop

A fixable hose has been used to complete the cycle. Those hose will not deal with high temperature or pressure, so we used a normal hose. Those hose work to deliver the water to each test tube inside the box.

7.3.6 Water outlet

In the end of the box a funnel has been blasted. This funnel function is colleting the heated water and delivered to the tank.

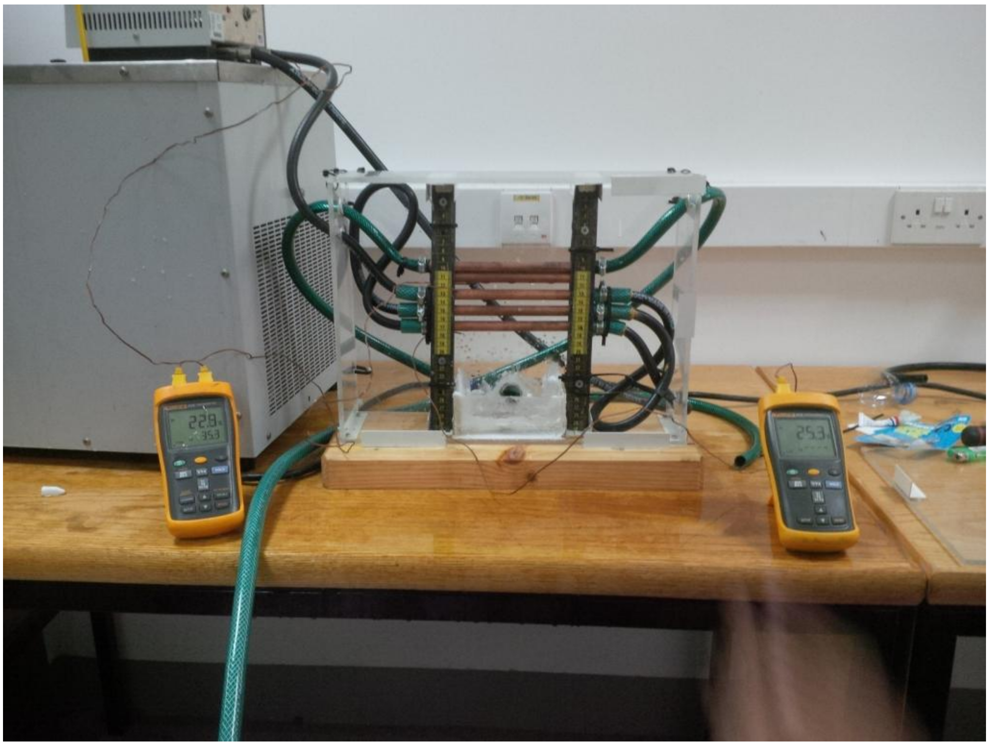


Figure 7- 3:prototype of heat exchange

7.4 Design dimensions

This test box made of fiberglass, which is a transparent sheet (for falling film and heat transfer) of 10 cm thickness, Test box inside dimensions 40x30x10 cm. The feed tube has a 12.7 mm diameter and 13.5 cm long. For this experimental we use a cupper tube as the test tube with 12.7 mm diameter and 13.5 cm long. To ensure continuous heat transfer we chose cooling path. In order to fix the test tube two bars are blasted.

7.5 Measurement

After assembly and arrangement the prototype parts together, we have to check the accurate of our project. In order to prove that the heat exchange it woke well a set of thermo couples and flow meter are fix to the prototype. We have measure the feed water and compared it with the outlet water.

CHAPTER 8: PROJECT EVALUATION

On this chapter, the impacts of the falling film heat exchanger will be discussed. These impacts include impact analysis, economic, potential, environmental and social.

8.1 Global impact

These type heat exchangers can be used as replacement of the some other type of heat exchangers. In this case it may have share in global market.

8.2 Economic impact

Economically the falling film heat exchanger can add a new production line in industry of heat exchanger in local and global economy that contributes to increase the need of employees, whichincrease in gross domestic product and also can decrease the unemployment rate in the country. On the other hand using falling film heat exchangers can reduce the operational and maintenance cost that reduce the need of employees. Politicallyall the industrial projects in Saudi Arabia supported by the government.

8.3 Environmental impact

Falling film heat exchangers are innocuous to the environment; there are no harmful emissions which reduce the influence ofglobal warming also the falling film heat exchanger not need to pumps power because the device depend on gravity that mean no energy loss can effect on the surrounding environment.

8.4 Social impact

With adding a new production line in industry field can provides job opportunities, which can reduce unemployment rate in the country. Falling film heat exchanger can save money because there is no need to pumps power and low cost of operational and maintenance process which can reduce the electricity bills for the citizens.

CHAPTER 9: CONCOLUSION

A heat exchanger with falling film technique has been designed. This artifact designed based on several studies. There were special constrains to take about it in this design. Such as the heated water should not exceed 43 ^{o}C, maximum flow rate of the cooling path is 4 kg/min and minimum flow rate of the falling film is 1 kg/ min.A test box has been designed, it consists of the test section, and the test section consisted of feed tubes, test tubes and funnel. All the tubes are made of copper, which has a high thermal conductivity. The feed tube is setup above the test section, its height is 300 mm the length is 400 mm and the width is 100 mm, diameter holes were drilled 2 mm apart from each other, providing 26 holes. The feed tube has inside and outside diameters of 12.7 mm and 10 mm. It receives liquid from a cooling path. Three test tubes configured above each other with diameter of 12.7 mm are placed at a pitch of 130 mm under the feed tubes. They were all held by the supporting box, which was made of neon transparent. The cooling path gave a capability of adjusting the temperature to keep it constant. It was used to supply hot water inside the test tubes. A constant temperature tap water provides pure water to the outside of the test tubes with different flow rate. Outlet temperature and flow rate of water, inside and outside the test tubes were recorded. Surface temperature was measured for one tube. Data acquired was used for temperature measurement.The average quantity of domestic water is 40 -30 lit/day in Saudi Arabia [11]. The following information includes the main technical specifications and operating data:Feeding water tube diameter = 12.7 mm, heat exchanger tube diameter = 12.7 mm, heat exchanger tube length = 135 mm, number of heat exchanger tube = 3 tubes, total area of heat exchanger tube (A_{dg}) = 0.041 m^2, inlet temperature of hot water ($T_{cp,i}$) = 80° C, feed water mas flow rate (m_{ff}) = 0.043 kg/s, hot water mass flow rate (m_{cp}) = 0.054 kg/s.

We had been through many steps until we were able to finish this project. We started with the project charter and the agreement with the customer, then we moved on to overall planning like constrains for the project, and using many techniques to decide how the project is going to be.

In the experimental design the team faced variable problems. In order to solve those problems, the team forced to change the prototype several time, into a new and better one with more improvement in each time. The last design was apple to reach to customer requirements. The last step was getting the product reading, so we run the prototype three times, now we can calculate the average to reach the best reading.

After finishing this project, the team learns so many things. For example, now each member understands the member responsibility to his team members. Also the ability of dealing with engineering problem has been improved.

REFERENCES

[1]: http://www.hcheattransfer.com/fouling1.html

[2]:http://en.wikipedia.org/wiki/Heat_exchanger

[3]: Hani. H.W. Sait "Experimental investigation on freezing of falling film" pp11, 1999

[4]:http://www.alhayat-j.com/newsite/details.php?opt=3&id=140680&cid=2257

[5]: http://en.wikipedia.org/wiki/White-box_testing.

[6]:http://en.wikipedia.org/wiki/Black_box

[7]: http://www.maxwideman.com/papers/lrc/intro.htm

[8]: Hani. H.W. Sait "Experimental investigation on freezing of falling film" pp13, 1999

[9]: Hani. H.W. Sait "Experimental investigation on freezing of falling film" pp13, 1999

[10]: Hani. H.W. Sait "Experimental investigation on freezing of falling film" pp16, 1999

[11]: Hani. H.W. Sait "Experimental investigation on freezing of falling film" pp16, 1999

[12]: Hani. H.W. Sait "Experimental investigation on freezing of falling film" pp18, 1999

[13]: Hani. H.W. Sait "Experimental investigation on freezing of falling film" pp18, 1999

[14]: Hani. H.W. Sait "Experimental investigation on freezing of falling film" pp18, 1999

[15]: Hani. H.W. Sait "Heat Transfer Characteristics and Temperature Distribution of Falling Film over Horizontal Hot Tube Arrays " pp 27, 2012

[16]: Hani. H.W. Sait "Heat Transfer Characteristics and Temperature Distribution of Falling Film over Horizontal Hot Tube Arrays " pp 27, 2012

[17]: Hani. H.W. Sait "Heat Transfer Characteristics and Temperature Distribution of Falling Film over Horizontal Hot Tube Arrays " pp 28, 2012

[18]: Hani. H.W. Sait "Heat Transfer Characteristics and Temperature Distribution of Falling Film over Horizontal Hot Tube Arrays " pp 28, 2012