

## TABLE OF CONTENTS

<b>ABSTRACT . . . . .</b>	<b>i</b>
<b>ACKNOWLEDGEMENTS . . . . .</b>	<b>ii</b>
<b>CHAPTER 1: INTRODUCTION . . . . .</b>	<b>1</b>
1.1 Background of Study . . . . .	1
1.2 Problem Statement . . . . .	2
1.3 Objectives . . . . .	2
1.4 Scope of study . . . . .	3
<b>CHAPTER 2: LITERATURE REVIEW . . . . .</b>	<b>4</b>
2.1 Critical review . . . . .	4
2.2 Selection of Heat Exchangers. . . . .	10
2.3 Common Failure Faced by Heat Exchanger in Industry . . . . .	10
2.4 Effects of Fouling . . . . .	11
2.5 Failure Analysis . . . . .	15
<b>CHAPTER 3: METHODOLOGY . . . . .</b>	<b>22</b>
3.1 Project Identification . . . . .	22
3.2 Pressure Testing . . . . .	24
3.3 Failure Analysis Methodology . . . . .	24
3.4 Root Cause Analysis (RCA) . . . . .	26
3.5 Steps of Research . . . . .	28
3.6 List of Tools/Equipments Required . . . . .	29

<b>CHAPTER 4:</b>	<b>RESULT &amp; DISCUSSION</b>	.	.	.	.	30
	4.1 Old Tube Bundle	.	.	.	.	30
	4.2 New Tube Bundle	.	.	.	.	44
<b>CHAPTER 5:</b>	<b>CONCLUSION &amp; RECOMMENDATION</b>	.	.	.	.	51
	5.1 Conclusion	.	.	.	.	51
	5.2 Recommendation	.	.	.	.	52
<b>REFERENCES</b>	.	.	.	.	.	<b>53</b>

## LIST OF FIGURE

Figure 3.1	E-105 after being removed from the shell	23
Figure 3.2	Thick brownish/slimy deposit/fouling observed next to tubing and baffle plate intersection	23
Figure 3.3	Coating damage and blister observed on E-105 tubing	23
Figure 3.4	Close-up of E-105 localized corrosion/pitting and groove/mechanical damage near baffle plate to tube intersection	23
Figure 3.5	Project Methodology work flow	27
Figure 4.1	As received E-105 with coating damage/blister on tubing external	31
Figure 4.2	E-105 with trough wall pitting 5mm x 6mm located next to baffle plate and tubing intersection. Smaller size pits observed in adjacent area	31
Figure 4.3	Cross-section view of E-105 through wall pit	36
Figure 4.4	Microstructure photo of tube E-105 taken from pit internal to external surface (d) and close-up view (e)	37
Figure 4.5	SEM photo from top surface E-105 pit hole	38
Figure 4.6	EDX analyses on corrosion product of E-105 tube	39
Figure 4.7	EDX analyses on black deposit	40
Figure 4.8	EDX Analysis on white deposit	41
Figure 4.9	XRD on black deposit	42
Figure 4.10	XRD on white deposit	43
Figure 4.11	Layer of deposits scale found at tubes and mostly accumulate at U-bend area [12]	44

Figure 4.12	View of tube bundle noted in satisfactory condition. No sign of any abnormalities observed [12]	45
Figure 4.13	Peeled off coating in some areas due to water jetting [12]	45
Figure 4.14	Touched-up peeled off coating after the contractor did hydro-jetting due to some damaged peeled off the existing coating [12]	46
Figure 4.15	View of tubes sheet found with thick layer of product residue and white residue stick at tubes sheet [12]	46
Figure 4.16	New E-15 Leaking Mapping [12]	47
Figure 4.17	Old E105 Leaking Mapping [12]	48
Figure 4.18	Sticky blackish deposited noted entire tube sheet surface [12]	48
Figure 4.19	Magnetic test carried out at deposited surface [12]	49
Figure 4.20	Summary of RCA [12]	50

## **LIST OF TABLE**

Table 3.1	LD1-11-E105 2 <sup>nd</sup> Stage Primary Heat Exchanger	22
Table 3.2	Tools/equipment required	29
Table 4.1	Tubing wall thickness measurement	31
Table 4.2	Tubing coating thickness measurement	32
Table 4.3	Cooling water analysis result	33
Table 4.4	Chemical composition analysis	34
Table 4.5	Tensile test result	35
Table 4.6	Micro-hardness measurement at different location from the pit	35

## **APPENDICES**

Appendix 1- Job Method Sheet PETLIN Turnaround 2009	I
Appendix 2- Gantt chart for FYP 1	II
Appendix 3- Gantt chart for FYP 1I	III
Appendix 4- Pictures of Old E-105	IV
Appendix 5- Performance of New Tube Bundle, E105	V
Appendix 6- Recommended Actions	VI