

## Table of Contents

Title Page .....	i
Abstract .....	ii
Acknowledgements .....	iii
Table of Contents .....	iv
List of Figures .....	vii
List of Nomenclature .....	x
1 Introduction .....	1
1.1 Motivation of Project .....	1
1.2 Original Computer Code of $T_{min}$ .....	3
1.3 Scope of this Thesis: Modifications to $T_{min}$ .....	4
1.4 Outline .....	5
2 Research Review .....	6
2.1 Background of Piping Stresses.....	7
2.1.1 Differential Stress Element Analysis .....	7
2.1.2 Mohr Circle Analysis .....	8
2.1.3 Maximum-Shear-Stress Theory .....	10
2.1.4 Pipe-Wall Theory .....	11
2.2 Piping Codes and Standards Requirements .....	16
2.2.1 Unfired Piping and Pressure Vessel Code .....	17
2.2.2 Criteria Document .....	20
3 Development of a Fatigue Curve Database and Implementation .....	29
3.1 Stress-Based Fatigue Analysis and Stress States.....	30
3.2 Creation of an Stress-Cycle Curve .....	34
3.3 Strain-Based Fatigue Analysis .....	38
3.4 Fatigue Data Obtained for $T_{min}$ .....	41
3.5 Calculation of Piping Fatigue Information and Implementation .....	47
4 Two-Axis Piping Span Stress Analysis Through $T_{min}$ .....	54
4.1 Shear and Moment Analysis .....	54

4.2 Shear and Moment Diagrams .....	57
4.3 Stress-Intensity Factors .....	59
4.4 Differential Stress Element Analysis of Piping Span .....	61
4.5 False-Position Root Solver .....	73
5 Modifications Applied to $T_{min}$ .....	76
5.1 User-Input Additions .....	76
5.2 Creation of 2-D Vertical Piping Span Output Form.....	82
5.3 Other $T_{min}$ Additions .....	87
6 Numerical Examples .....	88
6.1 First Vertical Span Example—Basic Piping Configuration .....	89
6.2 Second Piping Span Example—Shear Dominates .....	99
7 Conclusions and Future Recommendations .....	107
7.1 Conclusions .....	107
7.2 Recommendations .....	109
References .....	112
Appendix A – Shear Analysis for Vertical Piping .....	117
Appendix B – Fatigue Data Obtained for $T_{min}$ .....	136
Aluminum 1100 .....	137
Aluminum 3003-0 .....	139
Aluminum 6061-T6 .....	141
Nickel 200 .....	143
Appendix C – Matlab Code .....	145
Aluminum 1100 .....	146
Aluminum 3003-0 .....	156
Aluminum 6061-T6 .....	161
Nickel 200 .....	166
2-D Vertical Piping Span .....	171
Appendix D – Visual Basic Code Additions .....	179
2-D Vertical Piping Span Calculation Module Sub-Set.....	180
Span Choose Code and Form .....	211
Valve Connection Code and Form .....	213
2-D Vertical Analysis Form and Code .....	215
Bookmark Code .....	223
Copy Image Code .....	226

Call Macro Computer Code .....	235
Appendix E – Help File Creation and Output Documents.....	236
Creation of a Help file .....	237
Microsoft Word Document® Printouts .....	239
<i>Mathematica</i> ® Solutions .....	242
Vita .....	