

CONTENTS

<i>List of Tables</i>	ix
<i>List of Figures</i>	xi
<i>Acronyms and Abbreviations</i>	xiii
<i>Glossary</i>	xv
<i>Acknowledgments</i>	xxiii
<i>Online Materials Accompanying this Book</i>	xxvii
<i>Preface</i>	xxix

1	INTRODUCTION	1
1.1	Purpose.....	1
1.2	Scope and Intended Audience	1
1.3	Organization of this Concept Book	2
1.4	Introduction to the Bow Tie Concept.....	4
1.5	Conclusions.....	12
2	THE BOW TIE MODEL	15
2.1	Bow Tie Model Elements.....	15
2.2	Hazard.....	17
2.3	Top Event.....	20
2.4	Consequences.....	24
2.5	Threats.....	27
2.6	Barriers.....	32
2.7	Degradation Factors and Degradation Controls	45
2.8	Conclusions.....	51
3	BOW TIE DEVELOPMENT	53
3.1	Rationale for Bow Tie Development.....	53
3.2	Bow Tie Workshop	53
3.3	Post-Bow Tie Workshop Activities and Quality Checks	64
3.4	Conclusions.....	67

4	ADDRESSING HUMAN FACTORS IN BOW TIE ANALYSIS	69
4.1	Human and Organizational Factors Fundamentals.....	69
4.2	Standard and Multi-Level Bow Tie Approaches.....	74
4.3	Human and Organizational Factors as a Barrier or Degradation Control.....	80
4.4	Validating Human Performance in Barriers and Degradation Controls.....	84
4.5	Quantifying Human Reliability in Bow Ties.....	86
4.6	Conclusions.....	86
5	PRIMARY USES OF BOW TIES	89
5.1	Primary Use Examples.....	89
5.2	Linking Bow Ties to the Risk Management System.....	89
5.3	Communication of Major Accident Scenarios and Degradation Controls.....	94
5.4	Use of Bow Ties in Design and Operations.....	101
5.5	Identification of Safety Critical Information.....	107
5.6	Conclusions.....	113
6	BARRIER MANAGEMENT PROGRAM	115
6.1	Barrier Management Strategy.....	115
6.2	Barrier and Degradation Control Management Program.....	118
6.3	Organizational Learning.....	127
6.4	Conclusions.....	128
7	ADDITIONAL USES OF BOW TIES	131
7.1	Additional Use Examples.....	131
7.2	Linking Bow Ties to HAZOP, LOPA and SIL.....	131
7.3	Integrating Bow Ties into ALARP Demonstrations.....	134
7.4	Operationalizing Bow Ties (MOPO / SOOB).....	135
7.5	Incident Investigation using Bow Ties.....	139
7.6	Real-time Dashboards using Bow Ties.....	142
7.7	Barrier and Degradation Control Verification.....	143
7.8	Bow Tie Chaining.....	144
7.9	Enterprise-wide Analysis and Window on Systemic Risks.....	146
7.10	Conclusions.....	147

APPENDIX A – SOFTWARE TOOLS	149
Software used for Bow Tie Diagrams	149
APPENDIX B – CASE STUDY	153
Introduction	153
Volatile Hydrocarbons under Pressure in a Pipeline	153
APPENDIX C – MULTI-LEVEL BOW TIES	161
Multi-level Bow Tie for Tank Overfill.....	161
REFERENCES	171
INDEX	177

