

CONTENTS

	Page
FOREWORD	1
1 INTRODUCTION AND SCOPE	2
1.1 INTRODUCTION.....	2
1.2 SCOPE.....	2
1.3 DEFINITIONS	2
1.4 GENERAL RESPONSIBILITIES OF THE PURCHASER	3
1.5 PROJECT PLANNING	3
2 TYPES OF STORAGE VESSEL.....	4
2.1 SELECTION OF STORAGE VESSEL TYPE.....	4
2.2 MOUNDED STORAGE	4
3 FOUNDATION AND EARTH MOUND.....	6
3.1 INFORMATION REQUIRED BY THE CONTRACTOR.....	6
3.2 SOIL INVESTIGATION	6
3.2.1 Fieldwork	6
3.2.2 Laboratory Work	7
3.2.2.1 Classification Tests	8
3.2.2.2 Other Tests.....	8
3.2.3 Reporting	8
3.3 TYPES OF FOUNDATION.....	9
3.3.1 Soil Bearing FoundationS.....	9
3.3.2 Sandbed on Piled Concrete Slab	10
3.3.3 Vessels on Saddles	10
3.4 SETTLEMENT OF SOIL BEARING FOUNDATIONS	10
3.4.1 Immediate Settlements	10
3.4.2 Long-term Settlements	10
3.4.3 Total and Differential Settlements	11
3.5 SETTLEMENT MONITORING	11
3.5.1 Settlement Monitoring During Preloading.....	11
3.5.2 Settlement Monitoring During Operation	11
3.6 FOUNDATION DESIGN.....	12
3.6.1 General.....	12
3.6.2 Operational Phase of Vessel	12
3.6.3 Construction Phase of Vessel	12
3.7 MOUND DESIGN.....	13
3.7.1 Geometry.....	13
3.7.2 External Loads.....	13
3.7.3 Erosion Protection	13
3.8 FOUNDATION AND MOUND MATERIAL	14
3.9 CONSTRUCTION OF FOUNDATION AND MOUND	14
3.9.1 Foundation.....	14
3.9.2 Mound.....	15
4 VESSEL	16
4.1 DESIGN	16
4.1.1 General.....	16
4.1.2 Design Conditions	18
4.1.3 Design Loads.....	18
4.1.3.1 Dead Weight of the Vessel	18
4.1.3.2 Weight of Liquid in the Vessel.....	18
4.1.3.3 Internal Design Pressure.....	18
4.1.3.4 Negative Internal Pressure	20

4.1.3.5	Loads due to the Mound	20
4.1.3.6	Loads due to Uneven Support by the Foundation	20
4.1.3.7	Loads due to Temperature and Internal Pressure Variations.....	21
4.1.3.8	Loads due to Earthquake	21
4.1.3.9	Loads due to an External Explosion	21
4.1.4	Load Combinations.....	22
4.2	MATERIALS	22
4.3	CONSTRUCTION	23
4.3.1	Tolerances.....	23
4.3.2	Stiffeners	23
4.3.3	Welding.....	23
4.3.4	Heat Treatment.....	23
4.3.4.1	Pre-heat Treatment	23
4.3.4.2	Post-Weld Heat Treatment.....	24
4.4	FITTINGS FOR OPERATIONAL PURPOSES.....	24
4.4.1	General.....	24
4.4.2	Fittings for Product Inlet and Outlet	24
4.4.3	Piping.....	25
4.4.4	Drainage Facilities	25
4.4.5	Manholes	25
4.4.6	Sleeves Around Nozzles and Manholes	26
4.4.7	Instrumentation.....	26
4.4.7.1	General	26
4.4.7.2	Level Measuring Instruments.....	26
4.4.7.3	Level Alarms and Ullage Gauges	26
4.4.7.4	Pressure Indicators and Alarms	26
4.4.7.5	Vacuum Relief Valves.....	27
4.4.7.6	Temperature Measuring Devices and Indicators	27
4.4.7.7	Gas Detectors and Explosimeters	27
4.5	CORROSION PROTECTION	27
4.5.1	General.....	27
4.5.2	Coating	28
4.5.2.1	External Coating	28
4.5.2.2	Glass Fibre Reinforced Bitumen Coating System	28
4.5.2.3	Epoxy or Urethane Coating System	28
4.5.2.4	Coating Application	29
4.5.2.5	Coating Prequalification	29
4.5.2.6	Internal Coating.....	30
4.5.3	Cathodic Protection	30
4.5.3.1	General	30
4.5.3.2	Protection Criteria	30
4.5.3.3	Design	31
4.5.3.3.1	<i>Data to be Provided by Purchaser.</i>	31
4.5.3.3.2	<i>Soil Resistivity Measurements</i>	31
4.5.3.3.3	<i>Electrical Separation</i>	31
4.5.3.3.4	<i>Choice of Cathodic Protection System</i>	32
4.5.3.3.5	<i>Transformer-Rectifiers</i>	32
4.5.3.3.6	<i>Automatic Potential Control</i>	32
4.5.3.3.7	<i>Groundbeds</i>	33
4.5.3.3.8	<i>Monitoring Facilities</i>	33
4.5.3.3.9	<i>Cables and Distribution Boxes</i>	34
4.5.3.3.10	<i>Design Documents</i>	34
4.5.3.4	Installation	35
4.5.3.5	Commissioning	35
4.5.3.6	Operation and Maintenance	36
4.5.3.7	Special Design Considerations	36
4.6	LIGHTING PROTECTION.....	37

5 VESSEL: INSPECTION, TESTING AND CERTIFICATION	38
5.1 INSPECTION REQUIREMENTS, PROCEDURES AND STANDARDS	38
5.1.1 Procedures and Standards.....	38
5.1.2 Inspection Prior to Vessel Assembly	38
5.1.3 Inspection During Vessel Assembly	38
5.1.4 Inspection After Vessel Assembly	38
5.2 HYDROSTATIC PRESSURE TEST	38
5.3 MANUFACTURING REPORT	39
5.4 MARKING AND CERTIFICATION	39
6 GUIDELINES FOR IN-SERVICE INSPECTION	40
6.1 INSPECTION DURING OPERATION	40
6.1.1 Vessel.....	40
6.1.2 Vessel Settlement.....	40
6.1.3 Mound.....	40
6.2 TECHNICAL REVIEW.....	40
6.3 RECOMMENDED MINIMUM REQUIREMENTS FOR THE TECHNICAL INTEGRITY REVIEW	41
6.3.1 Recommended Actions Prior to Inspection	41
6.3.2 Recommended Actions Post-inspection.....	41
6.4 TYPICAL FAILURE MODES	42
6.5 RECOMMENDATIONS FOR PLANNING OF INSPECTION	42
7 REFERENCES	44
7.1 AMERICAN STANDARDS	44
7.2 BRITISH STANDARDS (including transposed ENs).....	44
7.3 INTERNATIONAL STANDARDS	45
7.4 MISCELLANEOUS CODES AND STANDARDS	45
7.5 RECOMMENDED FURTHER READING.....	46
8 GLOSSARY OF ABBREVIATIONS	47
APPENDIX A: STRESS ANALYSIS OF MOUNDED STORAGE VESSELS	49
A.1 INTRODUCTION.....	49
A.2 CIRCUMFERENTIAL BENDING.....	49
A.2.1 Unstiffened Cylinders	49
A.2.2 Stiffened Cylinders	49
A.3 NORMAL FORCES AND SHEAR FORCES	50
A.4 CALCULATION METHOD FOR STIFFENED CYLINDERS	50
A.4.1 Nomenclature	50
A.4.2 Loads.....	51
A.4.2.1 Dead Weight (Load 1).....	51
A.4.2.2 Weight of Liquid Fill (Load 2)	52
A.4.2.3 Internal Design Pressure (Load 3).....	52
A.4.2.4 Negative Internal Pressure (Load 4).....	52
A.4.2.5 Pressure Due to Mound (Load 5)	53
A.4.2.6 Load due to Uneven Support of the Vessel (Load 6)	54
A.4.2.7 Axial Loads due to Changes in Vessel Length (Load 7).....	55
A.4.2.8 Seismic Loads (Load 8)	55
A.4.2.9 External Pressure Caused by Explosion of Gas Clouds (Load 9)	56
A.4.2.10 Supporting Pressure by the Foundation (Load 10).....	56
A.4.3 Selection of Shell Plate Thickness	57
A.4.4 Bending Moments, Normal Forces and Shear Forces in Stiffening Rings.....	57
A.4.4.1 General	57
A.4.4.2 Bending Moments for 120° Support Angle	58
A.4.4.3 Normal Forces for 120° Support Angle	58
A.4.4.4 Shear Forces for 120° Support Angle	59
A.4.5 Bending Moments and Forces for 90° Support angle.....	60

A.4.6	Bending Moments and Forces for 60° Support angle.....	60
A.4.7	Dimensions of Stiffening Rings.....	60
A.4.8	Secondary Bending Stresses	61
A.4.9	Summary of Stresses	61
	A.4.9.1 Stresses in the Shell Plates.....	61
	A.4.9.1.1 <i>Circumferential Stresses in the Shell Plates</i>	61
	A.4.9.1.2 <i>Longitudinal Stresses in the Shell Plates</i>	62
	A.4.9.1.3 <i>Shear Stresses in the Shell Plates</i>	62
	A.4.9.1.4 <i>Stress Intensities in the Shell Plates</i>	63
	A.4.9.2 Stresses in the Domed Ends	63
	A.4.9.3 Stresses in the Stiffening Rings	63
	A.4.9.4 Stresses in the Welds between Stiffening Rings and Shell Plates	64
	A.4.9.5 Stability of Stiffening Rings.....	65
A.4.10	Stability of Stiffening Rings, Eurocode 3	66
	A.4.10.1 General	66
	A.4.10.2 Local Instability	67
	A.4.10.3 In-plane Buckling.....	67
	A.4.10.4 Shear Buckling of the Web	67
	A.4.10.5 Flange Induced Buckling.....	68
	A.4.10.6 Interaction between Buckling Modes	70
A.5	STRESS AND STABILITY CRITERIA	71
	A.5.1 General.....	71
	A.5.2 Shell Plates.....	72
	A.5.3 Domed Ends.....	72
	A.5.4 Stiffening Rings	73
A.6	DEFORMATION OF STIFFENING RINGS.....	73
APPENDIX B: TYPICAL DESIGN FEATURES FOR VESSEL, FOUNDATION AND CONNECTIONS		75
	B.1 FOUNDATION MODES	75
	B.2 MOUND.....	77
	B.3 VESSEL CONNECTIONS (CONCEPTUAL).....	79
	B.4 BOTTOM OUTLET WITH INSPECTION TUNNEL (CONCEPTUAL).....	80
APPENDIX C: DISTRIBUTION OF SOIL REACTION (SUPPORTING LOAD)		81
APPENDIX D: RECOMMENDED STEEL GRADES		82
APPENDIX E: PROJECT PLANNING.....		83
[APPENDIX F DELETED]		
APPENDIX G: NON-DESTRUCTIVE TESTING REQUIREMENTS		85
APPENDIX H: MATERIAL HARDNESS TESTING		87
APPENDIX I: SELECTION OF STORAGE SYSTEM.....		89