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Health and Safety Executive

Mechanical integrity management of bulk storage tanks

Review of standards

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Tony Holmes BSc PhD MRSC
Health and Safety Laboratory
Harpur Hill
Buxton
Derbyshire
SK17 9JN

Following the Buncefield incident the importance of preventing loss of containment from bulk storage tanks has come to the fore. A significant factor in ensuring contained fluids are not accidentally released is the continuing mechanical integrity of the tank structure. With this in mind, the joint industry/Competent Authority Process Safety Leadership Group has set up a working group to establish agreed industry standards for bulk storage tank integrity management.

The Health and Safety Laboratory was commissioned to produce a review of relevant published standards pertaining to the management of the mechanical integrity of bulk storage tanks. The findings from this review are reported here.

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HSE Books

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EXECUTIVE SUMMARY

The Buncefield incident demonstrated the importance of preventing loss of containment from bulk storage tanks. A significant factor in ensuring contained fluids are not accidentally released is the continuing mechanical integrity of the tank structure. This has prompted the Health and Safety Executive to consider establishing a set of enforceable standards for mechanical integrity management of bulk storage tanks. As part of this work the Health and Safety Laboratory was commissioned to undertake a review of existing standards, and to consider their suitability as components of a set of enforceable standards.

Following initial identification of standards, the most pertinent standards were obtained and reviewed. The coverage provided by each standard on mechanical engineering aspects through all stages of tank life was assessed, including design and construction, modifications, change of use, operation, inspection, testing, fitness for service, maintenance, repair, retirement, decommissioning and demolition. Summary tables were produced highlighting the coverage of each standard. A brief description of each standard has been provided, along with commentary on the suitability of the standard in terms of the extent and quality of coverage.

The review concluded that no single publication exists that can be considered suitable for recommendation as an overarching standard on the issue of mechanical integrity management of bulk storage tanks. This is because the publications give either a general, brief overview across a spectrum of issues, or specific, detailed guidance on a particular topic (for example, vent sizing) or group of topics (for example, inspection and maintenance).

If a recommendation is to be made to operators regarding the minimum standards acceptable for ensuring effective mechanical integrity management of bulk storage tanks, this will need to take the form of guidance identifying a collection of standards that, when taken together, encompass all the relevant issues. Suggestions of appropriate standards are provided in the discussion accompanying the review.

In addition to reviewing standards on mechanical integrity management of bulk storage tanks, a search was conducted to identify national and international guidance and standards covering wider integrity management issues, specifically on competency assurance and engineering records management. The search identified relatively few standards directed towards these areas.

1 INTRODUCTION

Following the Buncefield incident the importance of preventing loss of containment from bulk storage tanks has come to the fore. A significant factor in ensuring contained fluids are not accidentally released is the continuing mechanical integrity of the tank structure. With this in mind, the Health and Safety Executive's Process Safety Leadership Group has set up a working group to establish a set of enforceable standards for bulk storage tanks.

The Health and Safety Laboratory was commissioned to produce a review of relevant published standards pertaining to the management of the mechanical integrity of bulk storage tanks. The outcomes from this review are reported here.

The aims of the review were to:

- identify relevant national and international guidance and standards covering all aspects of the mechanical integrity management of bulk storage tanks (including installation, maintenance, inspection, repair, change of use, and retirement);

- identify relevant national and international guidance and standards covering wider integrity management issues, specifically in the areas of competency assurance and engineering records management; and

- collate and review the identified standards, providing an indication of how well each standard might reduce the risk of equipment failure.

Standards on the mechanical integrity management of tanks are reviewed in Section 2; the wider integrity management issues are dealt with in Section 3.

2 INTEGRITY MANAGEMENT OF BULK STORAGE TANKS

2.1 IDENTIFICATION OF STANDARDS

Standards of potential relevance were identified from the sources listed below.

- An initial list of standards provided by the HSE customer.
- HSE guidance on tank farms. [1, 2, 3]
- Searches through the online standards database from IHS, IHS Standards Expert (for details, refer to Appendix 1).
- Standards referenced by the other standards reviewed.

Table 1 lists the standards that were reviewed for this study, providing bibliographic details and a brief summary of the primary focus of the standard. In addition to the standards listed in Table 1 a number of standards were identified that were not reviewed, either because they were unobtainable at the time of the review or were considered unsuitable for inclusion. Details of these documents are provided in Appendix 1.

Table 1 Reviewed standards pertaining to the mechanical integrity management of bulk storage tanks

Standard	*Title*	*Year*	*Publishing body*	*Country*	*Status*	*Primary focus*
IP2	Design, Construction and Operation of Petroleum Distribution Installations – Model Code of Safe Practice in the Petroleum Industry – Part 2	2005	Energy Institute	UK	Current	Basic general guidance covering all aspects of petroleum distribution installations, not just tanks
EEMUA 159	Users Guide to the Maintenance and Inspection of Above-Ground Vertical Cylindrical Steel Storage Tanks	1994	The Engineering Equipment and Materials User Association	UK	Superseded by vol.1, 3rd edition, 2003 (vol. 1 of this edition was unobtainable at the time of this review)	Detailed coverage of inspection, repair and maintenance aspects, with appropriate references to other standards
EEMUA 159 vol.2	Users Guide to the Maintenance and Inspection of Above-Ground Vertical Cylindrical Steel Storage Tanks, 3rd Edition, Volume 2 (Appendices and list of references)	2003	The Engineering Equipment and Materials User Association	UK	Current	Appendices to vol.1 containing detailed information on calculations, repair solutions and inspection methodology
API 650	Welded Steel Tanks for Oil Storage, 11th Edition	2007	American Petroleum Institute	USA	Current	Detailed coverage of design, construction, and post-construction inspection
CIRIA 598	Chemical Storage Tank Systems – Good Practice	2003	CIRIA	UK	Current	General information on tank storage systems, with references to standards containing more detailed information
API 2000	Venting Atmospheric and Low-Pressure Storage Tanks	1998	American Petroleum Institute	USA	Current	Detailed coverage of venting requirements
API 653	Tank Inspection, Repair, Alteration and Reconstruction, 3rd edition incorporating addendum 1 and 2	2005	American Petroleum Institute	USA	Current	Inspection, repair, modification and reconstruction of tanks built to API 650 or API 12C

Standard	*Title*	*Year*	*Publishing body*	*Country*	*Status*	*Primary focus*
BS EN 14015	Specification for the design and manufacture of site built, vertical, cylindrical, flat-bottomed, above ground, welded, steel tanks for the storage of liquids at ambient temperature and above	2004	European Committee for Standardization	Europe	Current	Design and construction – detailed coverage and calculations
BS 2654	Specification for manufacture of vertical steel welded non-refrigerated storage tanks with butt-welded shells for the petroleum industry	1989	British Standards Institution	UK	Superseded by BS EN 14015	Design and construction – detailed coverage and calculations
ISO 28300	Petroleum, petrochemical and natural gas industries – Venting of atmospheric and low-pressure storage tanks	2008	International Standards Organisation	International [Based on API 2000, 5th Edition]	Current	Detailed coverage of venting requirements
API 620	Design and Construction of Large, Welded, Low-pressure Storage Tanks, 11th Edition	2008	American Petroleum Institute	USA	Current	Detailed coverage of design, construction, and post-construction inspection
API 2610	Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities	1994	American Petroleum Institute	USA	Current	General overview covering all aspects of petroleum terminal and tank facilities
HSE SPC/Tech/Gen /35	Integrity of Atmospheric Storage Tanks	2008	Health and Safety Executive	UK	Current guidance to HSE inspectors	Not a standard, but contains good general information on integrity management, with references to appropriate standards
HSG 176	The Storage of Flammable Liquids in Tanks	1998	Health and Safety Executive	UK	Current HSE guidance	Brief guidance on design, construction, operation and maintenance, with particular emphasis on dealing with flammable hazards

Standard	*Title*	*Year*	*Publishing body*	*Country*	*Status*	*Primary focus*
EEMUA 180	Guide for Designers and Users on Frangible Roof Joints for Fixed Roof Storage Tanks	1996	The Engineering Equipment and Materials User Association	UK	Current	Detailed guidance on ensuring effective frangible shell-roof connections
EEMUA 183	Guide for the Prevention of Bottom Leakage from Vertical, Cylindrical, Steel Storage Tanks	1999	The Engineering Equipment and Materials User Association	UK	Current	Guidance on the causes of bottom leakage, inspection and leak detection methods, and decision-making flowcharts
API 12B	Specification for Bolted Tanks for Storage of Production Liquids, 14th Edition	1995	American Petroleum Institute	USA	Current	Design and construction of bolted tanks
API 12R1	Recommended Practice for Setting, Maintenance, Inspection, Operation, and Repair of Tanks in Production Service, 5th Edition	1997	American Petroleum Institute	USA	Current	Maintenance, operation, inspection and repair of tanks built to API 12B, 12D, 12F, 12P
API RP 575	Guidelines and Methods for Inspection of Existing Atmospheric and Low-pressure Storage Tanks, 2nd Edition	2005	American Petroleum Institute	USA	Current	Maintenance and inspection of tanks built to API 12A, 12C, 620, and 650. Companion guide to API 653 standard

2.2 REVIEW OF STANDARDS

Each of the standards listed in Table 1 are reviewed in this section. The review begins with a series of summary tables giving an overview of the coverage provided by each standard. Following on from the tables is a brief review of each standard.

2.2.1 Summary tables

There follows a series of summary tables giving an overview of the coverage provided by each standard. These tables have been divided into categories for:

- Design and construction;
- Modifications;
- Change of Use;
- Operation;
- Inspection testing/ fitness for service;
- Maintenance and repair; and
- Retirement/decommissioning/demolition.

In the tables, the sections of the standard that refer to each item are given in brackets. Due to the size of the tables, it has been necessary to split some of them into several sections.

Table 2 Design and construction

Design and construction, Section 1 of 4

Coverage → ***↓Standard***	*In accordance with recognised standard*	*Consider roof loading, tank stability, and rate of corrosion where climatic conditions are severe*	*Special consideration for low temperature service*	*Design pressure*	*Venting – requirements and sizing*	*Emergency venting*	*Shell openings (including manholes and nozzles)*	*Drainage provision for floating roofs*	*Electrical earthing and bonding*	*Foundations*
IP 2	✓ (3.3.1.1)	✓ (3.3.1.2)	✓ (3.3.1.3)	✓ (3.3.2.1)	✓ (3.3.5)	✓ (3.3.5)	✓ (3.3.9, 3.3.12.5, 3.3.13.3) (Appendix P)	✓ (3.3.12, 3.3.13)	✓ (3.3.14)	✓ (3.3.16)
EEMUA 159					✓ (2.6.4) (2.6.4.4)					
EEMUA 159 Vol. 2					✓ (Appendix D.2)	✓ (Appendix D.2)				

Coverage → ***↓Standard***	*In accordance with recognised standard*	*Consider roof loading, tank stability, and rate of corrosion where climatic conditions are severe*	*Special consideration for low temperature service*	*Design pressure*	*Venting – requirements and sizing*	*Emergency venting*	*Shell openings (including manholes and nozzles)*	*Drainage provision for floating roofs*	*Electrical earthing and bonding*	*Foundations*
API 650	This is a recognised standard for design and construction				✓ (5.8.5)	✓ (5.8.5)	✓ (5.7)	✓ (Appendix C.3.8)		✓ (5.3) (Appendix B) (Appendix I)
CIRIA 598	✓ (3)				✓ (3.7)				✓ (5.5.5)	✓ (3.3.3)
API 2000					✓ (4.3)	✓ (4.3)				
API 653							✓ (8.5)			
BS EN 14015	This is a recognised standard for design and construction	✓ (B.2.2)		✓ (5.1)	✓ (10.6) (Annex L)		✓ (13) (16.9) (Annex O)	✓ (D.3.8)	✓ (13.14)	✓ (16.2) (Annex I)

Coverage → ***↓Standard***	*In accordance with recognised standard*	*Consider roof loading, tank stability, and rate of corrosion where climatic conditions are severe*	*Special consideration for low temperature service*	*Design pressure*	*Venting – requirements and sizing*	*Emergency venting*	*Shell openings (including manholes and nozzles)*	*Drainage provision for floating roofs*	*Electrical earthing and bonding*	*Foundations*
BS 2654	This is a recognised standard for design and construction			✓ (2.1)	✓ (8.6) (9.9) (Appendix F)	✓ (Appendix F)	✓ (11)		✓ (11.13)	✓ (Appendix A)
ISO 28300					✓ (4) (Annex A)	✓ (4) (Annex B)				
API 620	This is a recognised standard for design and construction			✓ (1.3.1)	✓ (Appendix K)	✓ (9) (Appendix N)	✓ (5.14) (5.15) (5.16) (5.17) (5.18) (5.19) (5.20) (5.21) (5.26)			✓ (Appendix C)

Coverage → ***↓Standard***	*In accordance with recognised standard*	*Consider roof loading, tank stability, and rate of corrosion where climatic conditions are severe*	*Special consideration for low temperature service*	*Design pressure*	*Venting – requirements and sizing*	*Emergency venting*	*Shell openings (including manholes and nozzles)*	*Drainage provision for floating roofs*	*Electrical earthing and bonding*	*Foundations*
API 2610	✓ (6.1.1)				✓ (6.1.6.1)	✓ (6.1.6.1)	✓ (6.1.6.4)	✓ (6.1.8)	✓ (6.1.6.8)	
HSE SPC/ Tech/Gen/ 35	✓									
HSG 176	✓ (61-62)				✓ (115-123)	✓ (115-123)	✓ (65)		✓ (134-136)	✓ (75)
EEMUA 180					✓ (3)	✓ (3)				✓ (7 – partial)
EEMUA 183										✓ (2)

Coverage → ***↓Standard***	*In accordance with recognised standard*	*Consider roof loading, tank stability, and rate of corrosion where climatic conditions are severe*	*Special consideration for low temperature service*	*Design pressure*	*Venting – requirements and sizing*	*Emergency venting*	*Shell openings (including manholes and nozzles)*	*Drainage provision for floating roofs*	*Electrical earthing and bonding*	*Foundations*
API 12B	This is a recognised standard for design and construction				✓ (Appendix B) (Appendix C)	✓ (Appendix C)				
API 12R1	✓ Refers to construction standards API 12B, 12D, 12F, 12P				✓ (Appendix B)	✓ (Appendix B)				
API RP 575										

Coverage → ***↓Standard***	*Corrosion protection – coating*	*Cathodic protection*	*Geodosic domes*	*Frangible roof joints*	*Roof seals*	*Material selection (and testing)*	*Joints and welds (and post-weld inspection)*	*Loads*	*Capacity*	*Corrosion allowances*
IP 2	✓ (3.3.18)	✓ (3.3.18)	✓ (3.3.21)							
EEMUA 159				✓ (2.6.4)	✓ (2.7.6)					
EEMUA 159 Vol. 2					✓ (Appendix D.3)					
API 650			✓ (Appendix G)			✓ (4)	✓ (5.1) (5.3.4) (7.2) (7.3.2) (9)	✓ (5.2) (Appendix P) (Appendix R)	✓ (5.2.6) (Appendix A)	✓ (5.3.2)
CIRIA 598	✓ (3.2.6)	✓ (3.2.7)				✓ (3.2)	✓ (5.5.2)			
API 2000										

Coverage → ***↓Standard***	*Corrosion protection – coating*	*Cathodic protection*	*Geodosic domes*	*Frangible roof joints*	*Roof seals*	*Material selection (and testing)*	*Joints and welds (and post-weld inspection)*	*Loads*	*Capacity*	*Corrosion allowances*
API 653							✓ (8.2) (8.3)			
BS EN 14015	✓ (Annex R)			✓ (10.3.2) (16.8.5) (Annex K)	✓ (11) (C.3.2.3) (Annex E)	✓ (5.2) (5.4) (6) (Annex F)	✓ (6.1.6.3) (9.5) (13) (17) (18) (Annex N)	✓ (7)		
BS 2654				✓ (F.4)	✓ (9.13)	✓ (2.2)	✓ (6.2) (7.5) (11.8) (15) (16)	✓ (5)	✓ (Appendix C)	
ISO 28300										

Coverage → ***↓Standard***	*Corrosion protection – coating*	*Cathodic protection*	*Geodosic domes*	*Frangible roof joints*	*Roof seals*	*Material selection (and testing)*	*Joints and welds (and post-weld inspection)*	*Loads*	*Capacity*	*Corrosion allowances*
API 620						✓ (4)	✓ (Figure 5-8) (5.16.8) (5.16.9) (5.22) (5.23) (5.24) (5.25) (6) (7.16) (Appendix H) (Appendix I) (Appendix P)	✓ (5.4)		✓ (5.7) (Appendix G)
API 2610	✓ (10.2) (10.3)	✓ (10.4)								
HSE SPC/ Tech/Gen/ 35										

Coverage → ***↓Standard***	*Corrosion protection – coating*	*Cathodic protection*	*Geodosic domes*	*Frangible roof joints*	*Roof seals*	*Material selection (and testing)*	*Joints and welds (and post-weld inspection)*	*Loads*	*Capacity*	*Corrosion allowances*
HSG 176	✓ (70-74)	✓ (70)								
EEMUA 180				✓ (Whole document)			✓ (7 – partial)			
EEMUA 183		✓ (6.6)								
API 12B							✓ (Appendix A)		✓	
API 12R1	✓ (4.4.4 – 4.4.5)	✓ (4.4.3)								
API RP 575										

Coverage → ***↓Standard***	*Tank bottom*	*Tank shell*	*Thermal stress relief*	*Attachments (includes stairs, wind girders, walkways)*	*Stiffening rings and wind girders*	*Roofs*	*Allowable stresses*	*Wind loadings and tank anchorage requirements*	*Fabrication and construction standards*	*Post construction testing*
IP 2										
EEMUA 159										
EEMUA 159 Vol. 2										
API 650	✓ (5.4)	✓ (5.6)	✓ (5.7.4)	✓ (5.8)	✓ (5.9)	✓ (5.10) (Appendix C) (Appendix H)	✓ (5.10.3)	✓ (5.11) (5.12)	✓ (6) (7) (9)	✓ (7.3)
CIRIA 598	✓ (3.3.3) (5.5.3)			✓ (3.3.3) (3.10.3)						✓ (5.10)
API 2000										
API 653		✓ (8.4)			✓ (8.6)	✓ (8.7)				

Coverage → ***↓Standard***	*Tank bottom*	*Tank shell*	*Thermal stress relief*	*Attachments (includes stairs, wind girders, walkways)*	*Stiffening rings and wind girders*	*Roofs*	*Allowable stresses*	*Wind loadings and tank anchorage requirements*	*Fabrication and construction standards*	*Post construction testing*
BS EN 14015	✓ (8) (16.6) (Annex H)	✓ (9) (16.7)		✓ (9.3) (13.11) (13.12) (13.13) (13.15) (13.16) (16.10) (16.11) (16.12) (Annex N)	✓ (9.3.1) (9.3.2) (9.3.3) (Annex J)	✓ (10) (11) (16.8) (Annex C) (Annex D)	✓ (9)	✓ (7.2.10) (12) (Annex M)	✓ (15) (16)	✓ (19)
BS 2654	✓ (6)	✓ (7)		✓ (11.10) (11.11) (11.12) (11.15) (11.16)	✓ (7.3)	✓ (8) (9) (Appendix E)		✓ (10) (G.4)	✓ (13) (14)	✓ (11.6) (17) (18)
ISO 28300										
API 620	✓ (5.10) (5.12)	✓ (5.9) (5.27)		✓ (Appendix E)	✓ (5.12.5) (5.13)	✓ (5.10) (5.11) (5.12)	✓ (5.5)		✓ (6)	
API 2610				✓ (6.1.6.10)						

Coverage → ***↓Standard***	*Tank bottom*	*Tank shell*	*Thermal stress relief*	*Attachments (includes stairs, wind girders, walkways)*	*Stiffening rings and wind girders*	*Roofs*	*Allowable stresses*	*Wind loadings and tank anchorage requirements*	*Fabrication and construction standards*	*Post construction testing*
HSE SPC/ Tech/Gen/ 35										
HSG 176								✓ (75)		
EEMUA 180	✓ (7 – partial)					✓ (7 – partial)				
EEMUA 183	✓ (3)									
API 12B	✓	✓		✓ (Appendix D)					✓	
API 12R1										✓ (4.4.2)
API RP 575										

Coverage → **↓ Standard**	*Tank name and marking plates*	*Seismic design*	*Insulation*	*Documentation requirements*
IP 2				
EEMUA 159			✓ (2.12)	
EEMUA 159 Vol. 2				
API 650	✓ (10)	✓ (Appendix E)		
CIRIA 598			✓ (3.3.3)	
API 2000				
API 653		✓ (8.8)		
BS EN 14015	✓ (20.2)	✓ (7.2.11) (Annex G)	✓ (Annex Q)	✓ (4) (20.1) (Annex A)

Coverage → **↓ Standard**	*Tank name and marking plates*	*Seismic design*	*Insulation*	*Documentation requirements*
BS 2654		✓ (5) (Appendix G)	✓ (12) (Appendix B)	✓ (3)
ISO 28300				
API 620	✓ (8)	✓ (Appendix L)		
API 2610				
HSE SPC/ Tech/Gen/ 35				
HSG 176				
EEMUA 180				
EEMUA 183				
API 12B				
API 12R1				

Coverage → **↓ Standard**	*Tank name and marking plates*	*Seismic design*	*Insulation*	*Documentation requirements*
API RP 575				✓ (10)

Table 3 Modifications

Coverage → ***↓Standard***	*In accordance with established standard*	*Increasing shell height*	*Shell penetrations/openings*	*Hot taps*	*Weakening fillet joint to make frangible shell-roof connection*	*Retrospective insertion of double bottom*
IP 2	✓ (2.4.1.6)					
EEMUA 159						
EEMUA 159 Vol. 2						
API 650						
CIRIA 598						
API 2000						
API 653	✓ (9.1)	✓ (9.5)	✓ (9.9)	✓ (9.14)		
BS EN 14015						
BS 2654						
ISO 28300						
API 620						
API 2610						

Coverage → ***↓Standard***	*In accordance with established standard*	*Increasing shell height*	*Shell penetrations/openings*	*Hot taps*	*Weakening fillet joint to make frangible shell-roof connection*	*Retrospective insertion of double bottom*
HSE SPC/ Tech/Gen/ 35						
HSG 176						
EEMUA 180					✓ (7.3)	
EEMUA 183						✓ (3.4)
API 12B						
API 12R1		✓ (7.5)		✓ (7.7)		
API RP 575						

Table 4 Change of use

Coverage → ***↓Standard***	*Consider design pressure when changing use*	*Operation at elevated temperature*	*Operation at temperatures lower than design temperature*	*Venting considerations*
IP 2	✓ (3.3.2.1)			
EEMUA 159				
EEMUA 159 Vol. 2				
API 650				
CIRIA 598				
API 2000				
API 653	✓ (4.2.4)	✓ (4.2.4.3) (4.3.10.2)	✓ (4.2.4.4)	✓ (4.2.4.5)
BS EN 14015				
BS 2654				
ISO 28300				
API 620				

Coverage → ***↓Standard***	*Consider design pressure when changing use*	*Operation at elevated temperature*	*Operation at temperatures lower than design temperature*	*Venting considerations*
API 2610				
HSE SPC/ Tech/Gen/ 35				
HSG 176				
EEMUA 180				
EEMUA 183				
API 12B				
API 12R1				
API RP 575				

Table 5 Operation

Only operating procedures of particular relevance to mechanical integrity are included

Coverage → **↓ Standard**	Avoid water bottoms to minimise corrosion	Control fill/empty rate to match venting capability	Boil-over prevention	Operation of roof drain valves – freezing of rainwater	Operation of roof drain valves – inspect to ensure no product leakage
IP 2	✓ (4.5.4)				
EEMUA 159		✓ (2.6.4.4)	✓ (2.6.4.4)		
EEMUA 159 Vol. 2					
API 650					
CIRIA 598					
API 2000					
API 653					
BS EN 14015					
BS 2654				✓ (9.15.2)	✓ (9.15.2)
ISO 28300					
API 620					

Coverage → **↓ Standard**	Avoid water bottoms to minimise corrosion	Control fill/empty rate to match venting capability	Boil-over prevention	Operation of roof drain valves – freezing of rainwater	Operation of roof drain valves – inspect to ensure no product leakage
API 2610					
HSE SPC/ Tech/Gen/ 35					
HSG 176					
EEMUA 180					
EEMUA 183					
API 12B					
API 12R1		✓ (5.1.12)			
API RP 575					

Table 6 Inspection/testing/fitness for service

Inspection / testing / fitness for service, section 1 of 5

Coverage → ***↓Standard***	*Inspect in accordance with original design standard/ inspection standard*	*Soil settlement*	*Pipe connections and pipe bellows*	*Floor – testing for leaks*	*Hydrotest*	*Vapour tightness testing of roof*	*Controlled water loading of new tanks*	*Corrosion – bottom plates - underside*	*Corrosion – bottom plates - topside*
IP 2	✓ (3.3.17)			✓ (3.3.17)	✓ (3.3.17)	✓ (3.3.17)	✓ (3.3.17)		
EEMUA 159	✓ (2.1)	✓ (2.2)	✓ (2.2.2)	✓ (2.13.1.1)	✓ (4)			✓ (2.3.2)	✓ (2.3.2)
EEMUA 159 Vol. 2									
API 650	✓				✓ (7.3.6)	✓ (7.3.7)	✓ (7.3.6)		
CIRIA 598				✓ (3.6.6)	✓ (5.10.2)		✓ (5.10.2)		
API 2000									

Coverage → ***↓Standard***	*Inspect in accordance with original design standard/ inspection standard*	*Soil settlement*	*Pipe connections and pipe bellows*	*Floor – testing for leaks*	*Hydrotest*	*Vapour tightness testing of roof*	*Controlled water loading of new tanks*	*Corrosion – bottom plates - underside*	*Corrosion – bottom plates - topside*
API 653	This standard outlines requirements based on sister standard for design / construction, API 650	✓ (Appendix B)	✓ (Appendix C)	✓ (Appendix C)	✓ (12.3) (12.5)	✓ (4.2.3)		✓ (4.4)	✓ (4.4)
BS EN 14015					✓ (19.13)		✓ (19.13)		
BS 2654							✓ (18.4) (A.5)		
ISO 28300									
API 620					✓ (7.18)		✓ (7.18)		
API 2610	✓ (6.2.1)								

Coverage → ***↓Standard***	*Inspect in accordance with original design standard/ inspection standard*	*Soil settlement*	*Pipe connections and pipe bellows*	*Floor – testing for leaks*	*Hydrotest*	*Vapour tightness testing of roof*	*Controlled water loading of new tanks*	*Corrosion – bottom plates - underside*	*Corrosion – bottom plates - topside*
HSE SPC/ Tech/Gen/ 35	✓		✓ (142-146)		✓ (160-165)				
HSG 176									
EEMUA 180									
EEMUA 183	✓ (5.1.1)	✓ (4.3)		✓ (7)				✓ (4.4)	✓ (4.4)
API 12B									
API 12R1		✓ (6.7)			✓ (4.4.2)	✓ (4.4.2)	✓ (4.4.2)		✓ (6.5)
API RP 575	This is a recommended practice for tank inspection. Reference is made to the associated standard API 653	✓ (5.4)	✓ (5.5)	✓ (8)	✓ (7.4.6) (7.5)			✓ (5.2.1) (7.3.1)	✓ (5.2.2)

Coverage → ***↓ Standard***	*Corrosion - shell plates*	*Corrosion – roof*	*Corrosion under insulation*	*Maximum allowable settlement - calculations*	*Unsupported bulges in floor – guidance on when to repair*	*Shell plates – minimum allowable thickness – calculations*	*Inspecting for corrosion at wind girders and attachments*	*Shell buckling*	*Inspection of manholes, nozzles, openings*
IP 2									
EEMUA 159	✓ (2.3.3)	✓ (2.3.4) (2.6)	✓ (2.3.4) (2.5.2) (2.12)	✓ (2.2) (2.4.1) (2.4.3)	✓ (2.4.3)	✓ (2.5.1) (2.10)	✓ (2.5.2)	✓ (2.5.3)	✓ (2.5.4) (2.5.5)
EEMUA 159 Vol. 2						✓ (Appendix A)			
API 650									
CIRIA 598									
API 2000									
API 653	✓ (4.3)	✓ (4.2)	✓ (Appendix C)	✓ (Appendix B.3)		✓ (4.3.3)	✓ (4.3.7)	✓ (4.3.5)	✓ (4.3.9) (12.1.2)
BS EN 14015									
BS 2654									

Coverage → ***↓Standard***	*Corrosion - shell plates*	*Corrosion – roof*	*Corrosion under insulation*	*Maximum allowable settlement - calculations*	*Unsupported bulges in floor – guidance on when to repair*	*Shell plates – minimum allowable thickness – calculations*	*Inspecting for corrosion at wind girders and attachments*	*Shell buckling*	*Inspection of manholes, nozzles, openings*
ISO 28300									
API 620									
API 2610									
HSE SPC/ Tech/Gen/ 35			✓ (83 – 107)						
HSG 176			✓ (74)						
EEMUA 180									
EEMUA 183									
API 12B									
API 12R1	✓ (6.5)	✓ (6.7)							
API RP 575	✓ (5.2.1) (5.2.2) (7.2.8) (7.4.5)	✓ (7.2.9) (7.3.3)	✓ (7.2.7)				✓ (5.5) (7.2.8.2)		✓ (5.4) (7.4.4)

Inspection / testing / fitness for service, section 3 of 5

Coverage → ***↓Standard***	*Roof plates – minimum allowable thickness - calculations*	*Vent, vacuum valve, pressure valve inspection*	*Pontoon compartment – leak inspection*	*Roof fatigue cracking*	*Roof drain inspection*	*Roof seal inspection*	*Out of roundness tolerances*	*Ladder, stair, walkway inspection*	*Instrumentation inspection*
IP 2									
EEMUA 159	✓ (2.6.2) (2.10.5)	✓ (2.6.4)	✓ (2.7.2)	✓ (2.7.3)	✓ (2.7.4)	✓ (2.7.6)	✓ (2.7.7)	✓ (2.7.9) (2.8)	✓ (2.9)
EEMUA 159 Vol. 2	✓ (Appendix A)								
API 650									
CIRIA 598									
API 2000		✓ (4.5) (4.6)							
API 653	✓ (4.2)	✓ (Appendix C)	✓ (4.2.3)	✓ (4.2.3)	✓ (4.2.3)	✓ (4.2.3)	✓ (4.3.5)	✓ (4.2.3)	✓ (Appendix C)
BS EN 14015									

Coverage → ***↓Standard***	*Roof plates – minimum allowable thickness - calculations*	*Vent, vacuum valve, pressure valve inspection*	*Pontoon compartment – leak inspection*	*Roof fatigue cracking*	*Roof drain inspection*	*Roof seal inspection*	*Out of roundness tolerances*	*Ladder, stair, walkway inspection*	*Instrumentation inspection*
BS 2654			✓ (9.15.2)						
ISO 28300		✓ (6)							
API 620									
API 2610									
HSE SPC/ Tech/Gen/ 35		✓ (147-152)							
HSG 176									
EEMUA 180									
EEMUA 183									
API 12B									
API 12R1									
API RP 575		✓ (5.5) (7.3.4)	✓ (5.5) (7.3.3)		✓ (5.5) (7.2.9) (7.3.3)	✓ (5.4) (7.2.9) (7.3.3)		✓ (5.5) (7.2.1) (7.2.2)	✓ (5.5) (7.2.10)

Coverage → ***↓ Standard***	*Ultrasonic testing*	*Floor plates – minimum allowable thickness – calculations*	*Coating inspection*	*Inspection records and related documentation*	*Inspection checklist*	*Inspection frequencies*	*Stability calculations (stresses, loads, buckling etc)*	*Remaining life & fitness for service calculations*	*Failure modes*
IP 2									
EEMUA 159	✓ (2.10)	✓ (2.10.4)	✓ (2.11)	✓ (2.13)	✓ (2.13.1.1)	✓ (2.13.2)			
EEMUA 159 Vol. 2	✓ (Appendix A)	✓ (Appendix A)		✓ (Appendix A)	✓ (Appendix B)	✓ (Appendix B, Appendix E)	✓ (Appendix D.1)	✓ (Appendix D.4, Appendix E)	✓ (Appendix E.2)
API 650	✓ (8.3)								
CIRIA 598						✓ (6.6.1)			✓ (Appendix A1)
API 2000									
API 653	✓ (Section 6)	✓ (4.4.7)	✓ (6.3.3)	✓ (6.8)	✓ (6.7)	✓ (6.2) (6.4.2)		✓ (Section 4) (Section 5)	✓ (Section 4) (Section 5)

Coverage → ***↓Standard***	*Ultrasonic testing*	*Floor plates – minimum allowable thickness – calculations*	*Coating inspection*	*Inspection records and related documentation*	*Inspection checklist*	*Inspection frequencies*	*Stability calculations (stresses, loads, buckling etc)*	*Remaining life & fitness for service calculations*	*Failure modes*
BS EN 14015	✓ (19.10 – refers to EN 1714)								
BS 2654									
ISO 28300									
API 620	✓ (5.26) (7.15.3) (7.17)								
API 2610					✓ (6.2.1)				
HSE SPC/ Tech/Gen/ 35	✓ (83 – 107)			✓ (20-30) (115-122)		✓ (109-114)			✓ (31-
HSG 176				✓ (194)					
EEMUA 180									✓ (6)

Coverage → ***↓Standard***	*Ultrasonic testing*	*Floor plates – minimum allowable thickness – calculations*	*Coating inspection*	*Inspection records and related documentation*	*Inspection checklist*	*Inspection frequencies*	*Stability calculations (stresses, loads, buckling etc)*	*Remaining life & fitness for service calculations*	*Failure modes*
EEMUA 183	✓ (5.2.2.3) (5.2.3)	✓ (4.4.5)		✓ (5.1)					✓ (4)
API 12B									
API 12R1					✓ (Appendix D) (Appendix E) (Appendix G) (Appendix H)	✓ (6.1) (6.6)		✓ (6.1)	
API RP 575	✓ (8) (Appendix A)		✓ (7.2.6)	✓ (10)		✓ (6) (Appendix B)		✓ (6)	✓ (5.2)

Coverage → ***↓Standard***	*Radiography*	*Magnetic particle and magnetic flux leakage testing*	*Liquid penetrant testing*	*Visual inspection*	*Inspector certification/ competency*	*Selection of non-destructive test methods*	*Vacuum box testing*	*Endoscopy*	*Detectable gas inspections*
IP 2									
EEMUA 159									
EEMUA 159 Vol. 2									
API 650	✓ (8.1)	✓ (8.2)	✓ (8.4)	✓ (8.5)					
CIRIA 598									
API 2000									
API 653	✓ (12.2) (Appendix F)	✓ (Appendix F)	✓ (Appendix F)	✓ (Appendix C) (Appendix F)	✓ (Appendix D)	✓ (12) (Appendix F)			
BS EN 14015	✓ (19.4.4)	✓ (19.4.4) (19.7)	✓ (19.4.4) (19.6)	✓ (19.4.3) (19.4.4)			✓ (19.4.4) (19.5)		
BS 2654	✓ (17)								

Coverage → ***↓Standard***	*Radiography*	*Magnetic particle and magnetic flux leakage testing*	*Liquid penetrant testing*	*Visual inspection*	*Inspector certification/ competency*	*Selection of non-destructive test methods*	*Vacuum box testing*	*Endoscopy*	*Detectable gas inspections*
ISO 28300									
API 620	✓ (5.26) (7.15.1) (7.17)	✓ (7.15.2)	✓ (7.15.4)	✓ (7.15.5)	✓ (7.2)				
API 2610									
HSE SPC/ Tech/Gen/ 35	✓ (83 – 107)		✓ (83 – 107)	✓ (83 – 107)	✓ (77 – 82)		✓ (83 – 107)		
HSG 176		✓							
EEMUA 180									
EEMUA 183		✓ (5.2.2.2)					✓ (5.2.2.1)	✓ (5.2.3.3)	
API 12B									
API 12R1					✓ (Appendix A)				
API RP 575		✓ (8) (Appendix A)	✓ (8)	✓ (5) (7) (8)		✓ (Appendix A)	✓ (8)		✓ (8)

Table 7 Maintenance and repair

Maintenance and repair, section 1 of 3

Coverage → ***↓Standard***	*Rectifying pipe connection / bellow problems following settlement*	*Rectifying tank settlement/ foundation issues*	*Internal coating*	*Removing floor ripples formed during water test*	*Repair of unsupported floor bulges*	*Repair of buckled shells*	*Temporary clean-out openings - construction*	*Temporary repair to fatigue cracked roof*	*External coating*
IP 2									
EEMUA 159	✓ (2.2)	✓ (2.2)	✓ (2.3.3) (2.11.3)	✓ (2.4.2)	✓ (partial) (2.4.3)	✓ (2.5.3)	✓ (2.5.5)	✓ (2.7.3)	✓ (2.11.2)
EEMUA 159 Vol. 2		✓ (Appendix C.2)	✓ (Appendix C.5)						✓ (Appendix C.5)
API 650									
CIRIA 598			✓ (6.8.2)		✓ (6.4.5)				✓ (6.4.3)
API 2000									
API 653		✓ (Appendix B)							

Coverage → ***↓Standard***	*Rectifying pipe connection / bellow problems following settlement*	*Rectifying tank settlement/ foundation issues*	*Internal coating*	*Removing floor ripples formed during water test*	*Repair of unsupported floor bulges*	*Repair of buckled shells*	*Temporary clean-out openings - construction*	*Temporary repair to fatigue cracked roof*	*External coating*
BS EN 14015			✓ (Annex R)						✓ (Annex R)
BS 2654									
ISO 28300									
API 620									
API 2610			✓ (10.3)						✓ (10.2)
HSE SPC/ Tech/Gen/ 35									
HSG 176									
EEMUA 180									
EEMUA 183			✓ (6.2)						
API 12B									

Coverage → ***↓Standard***	*Rectifying pipe connection / bellow problems following settlement*	*Rectifying tank settlement/ foundation issues*	*Internal coating*	*Removing floor ripples formed during water test*	*Repair of unsupported floor bulges*	*Repair of buckled shells*	*Temporary clean-out openings - construction*	*Temporary repair to fatigue cracked roof*	*External coating*
API 12R1			✓ (4.4.4 – 4.4.5)						
API RP 575									

Maintenance and repair, section 2 of 3

Coverage → ***↓Standard***	*Insulation*	*Jacking procedures*	*Repairing tank bottoms*	*Repairing tank shells*	*Weld and joints during repairs/weld repairs*	*Venting, valve and gauges*	*Materials considerations*	*Repairing, replacing or adding shell openings/ penetrations (nozzles, man holes etc)*	*Roof repairs*
IP 2									
EEMUA 159	✓ (2.12)								

Coverage → ***↓Standard***	*Insulation*	*Jacking procedures*	*Repairing tank bottoms*	*Repairing tank shells*	*Weld and joints during repairs/weld repairs*	*Venting, valve and gauges*	*Materials considerations*	*Repairing, replacing or adding shell openings/ penetrations (nozzles, man holes etc)*	*Roof repairs*
EEMUA 159 Vol. 2		✓ (Appendix C)	✓ (Appendix C.3)	✓ (Appendix C.4)					
API 650					✓ (7.4)				
CIRIA 598				✓ (6.4.5)					
API 2000						✓ (4.5)			
API 653			✓ (9.10) (12.1.7)	✓ (9.2) (9.3) (9.4) (12.1.4) (12.1.5) (12.1.6) (12.1.8)	✓ (9.6) (12.1.3) (12.2)		✓ (7)	✓ (9.7) (9.8) (12.1.2)	✓ (9.11) (9.12)

Coverage → ***↓Standard***	*Insulation*	*Jacking procedures*	*Repairing tank bottoms*	*Repairing tank shells*	*Weld and joints during repairs/weld repairs*	*Venting, valve and gauges*	*Materials considerations*	*Repairing, replacing or adding shell openings/ penetrations (nozzles, man holes etc)*	*Roof repairs*
BS EN 14015									
BS 2654									
ISO 28300									
API 620									
API 2610									
HSE SPC/ Tech/Gen/ 35									
HSG 176									
EEMUA 180									
EEMUA 183									
API 12B									
API 12R1				✓ (7)	✓ (7.4.2)				

Coverage → ***↓Standard***	*Insulation*	*Jacking procedures*	*Repairing tank bottoms*	*Repairing tank shells*	*Weld and joints during repairs/weld repairs*	*Venting, valve and gauges*	*Materials considerations*	*Repairing, replacing or adding shell openings/ penetrations (nozzles, man holes etc)*	*Roof repairs*
API RP 575			✓ (9.2.3)	✓ (9.2.4)	✓ (9.2.1)				✓ (9.2.5)

Maintenance and repair, section 3 of 3

Coverage → ***↓Standard***	*Repairing floating roof seals*	*Hot taps*	*Complete reconstruction of previously dismantled tank*	*Marking / nameplates for reconstructed tanks*	*Maintenance record keeping*	*Certification of reconstructed tanks*
IP 2						
EEMUA 159						
EEMUA 159 Vol. 2						
API 650						
CIRIA 598						

Coverage → ***↓Standard***	*Repairing floating roof seals*	*Hot taps*	*Complete reconstruction of previously dismantled tank*	*Marking / nameplates for reconstructed tanks*	*Maintenance record keeping*	*Certification of reconstructed tanks*
API 2000						
API 653	✓ (9.13)	✓ (9.14) (12.1.2)	✓ (10.4) (10.5)	✓ (13.1)	✓ (13.2)	✓ (13.3)
BS EN 14015						
BS 2654						
ISO 28300						
API 620						
API 2610						
HSE SPC/ Tech/Gen/ 35						
HSG 176						
EEMUA 180						
EEMUA 183						
API 12B						

Coverage → ***↓Standard***	*Repairing floating roof seals*	*Hot taps*	*Complete reconstruction of previously dismantled tank*	*Marking / nameplates for reconstructed tanks*	*Maintenance record keeping*	*Certification of reconstructed tanks*
API 12R1			✓ (7.9)			
API RP 575					✓ (10)	

Table 8 Retirement/decommissioning/demolition

Coverage → ***↓ Standard***	*Seal manholes to prevent access*	*Rest floating roofs on legs*	*Follow appropriate code of practice on demolition*	*Cleaning and gas freeing prior to demolition*	*Dismantling methods - shell*	*Dismantling methods - roof*	*Dismantling methods - floor*	*Piece labelling when dismantling with intention to reconstruct*
IP 2	✓ (8.3.3)	✓ (8.3.3)	✓ (8.4)					
EEMUA 159								
EEMUA 159 Vol. 2								
API 650								
CIRIA 598								
API 2000								
API 653				✓ (10.2)	✓ (10.3.3)	✓ (10.3.4)	✓ (10.3.3)	✓ (10.3.5)
BS EN 14015								
BS 2654								
ISO 28300								
API 620								

Coverage → ***↓Standard***	*Seal manholes to prevent access*	*Rest floating roofs on legs*	*Follow appropriate code of practice on demolition*	*Cleaning and gas freeing prior to demolition*	*Dismantling methods - shell*	*Dismantling methods - roof*	*Dismantling methods - floor*	*Piece labelling when dismantling with intention to reconstruct*
API 2610								
HSE SPC/ Tech/Gen/ 35								
HSG 176								
EEMUA 180								
EEMUA 183								
API 12B								
API 12R1								
API RP 575								

2.2.2 Overviews of individual standards

This section provides a brief review of each standard, summarising the coverage and strengths of each document. An attempt is made to assess whether the standards are suitable to form the basis of guidance on managing the mechanical integrity of bulk atmospheric storage tanks.

IP 2: Design, Construction and Operation of Petroleum Distribution Installations – Model Code of Safe Practice in the Petroleum Industry

This publication presents a general overview of all aspects of petroleum distribution installations, from the initial planning stage to construction and operation. Coverage of individual issues is generally brief, but provides a good insight into all the considerations required for safe operation of petroleum distribution facilities. This includes site security, tankage layout, tanks, cargo transfer facilities, health and safety management, emergencies, and closure and demolition.

The mechanical integrity of atmospheric storage tanks is not the primary focus of the publication, but there is overview coverage of this issue. There is detail regarding the required number, location and size of manholes, and also the provision of water drainage for floating roofs. Basic detail on engineering records management is included.

IP 2 is not suitable as a sole recommended standard for mechanical integrity management of atmospheric storage tanks. The publication should be viewed as an informational piece to alert operators to the issues they should consider, and one that provides references to publications presenting more detailed coverage.

EEMUA 159: Users Guide to the Maintenance and Inspection of Above-Ground Vertical Cylindrical Steel Storage Tanks

The latest version of this publication (3rd Edition 2003, with corrigenda February 2004) was not available at the time of this review, so the 1994 edition was reviewed. This edition of EEMUA 159 focuses on issues around the inspection of tanks, and the ageing processes relevant to each part of the tank. The latest edition of EEMUA 159 has additional sections on repairs.

EEMUA 159 presents detailed information on common failure modes for tanks, including problems with settlement, wind damage, corrosion, and drains and seals for floating roofs. The guide includes checklists for use during inspections, recommended inspection frequencies, which inspection methods to use, and how to interpret inspection data. References to appropriate standards are given.

The best coverage in this publication is on foundations and settlement (including limits of allowable settlement), floating roof drains and seals, and allowable plate thicknesses. Inspection is well covered, particularly regarding inspection checklists, though the technical details (calculations, fitness for service, corrosion limits) is not particularly in-depth. These are presented in Volume 2 of the publication.

EEMUA 159 is not intended to inform the design and construction of tanks, and nor does it provide detailed coverage on repair solutions, though there is some good coverage of remediation of settlement.

EEMUA 159 Vol.2: Users Guide to the Inspection, Maintenance and Repair of Above-Ground Vertical Cylindrical Steel Storage Tanks

Volume 2 of the 3rd edition of EEMUA 159 contains technical appendices to the main volume. A summary of the coverage is given below.

- Detailed checklists for in-service and out-of service inspections, with recommended inspection frequencies.
- Typical repair solutions, including detailed information on jacking procedures and replacing of plates.
- Calculations for determining stability of corroded tanks and remaining life of storage tanks.
- Calculations for vent sizing.
- Calculations for use in floating roof seal design.
- Detailed guidance on risk-based inspection and maintenance regimes (probabilistic preventative maintenance).

This volume of EEMUA 159 adds technical detail to the information presented in Volume 1. The section on probabilistic preventative maintenance has good detail, and guides users on tank failure modes, consequences, effects, and causes. Methods are presented for calculating inspection intervals based on failure probabilities and consequence rating.

API 650: Welded Steel Tanks for Oil Storage

This publication includes thorough coverage of the design and construction elements of atmospheric storage tanks.

Tank design is presented in terms of who (commissioner/construction contractor) should be responsible for each aspect of the design. Detailed discussion of tank design and material specifications is included, including relevant engineering calculations, and diagrams of structural features.

Construction coverage includes weld details, construction standards and dimensional tolerances. The quality of welds is discussed at length, as are the various methods for inspecting welds following construction. Post-construction testing, for example hydrotesting, is discussed.

The appendices present further detailed information on particular topics, including foundations, floating roofs, seismic design, and allowable loads.

The strength of API 650 lies in its detailed coverage of construction and design. Coverage does not extend to operation, inspection (other than post-construction inspection) and maintenance; these are covered in the companion standard API 653.

CIRIA 598: Chemical Storage Tank Systems – Good Practice

This CIRIA publication contains general information on good practice across a range of issues relating to storage tank systems. Coverage of each issue is generally brief, and discussion of mechanical integrity issues comprises only a small part of the publication. The text includes references to relevant standards, guidance, and legislation containing more detailed information on the issues discussed.

The publication contains good diagrams illustrating good and bad practice for tank foundations and insulation. Good coverage is also provided on bunding, and tank base and annular ring construction. The guide also gives a useful indication of possible future developments in good practice.

There is brief guidance on basing inspection frequencies on risk, but guidance on recommended inspection frequencies is not provided.

Appendix 1 reviews the possible failure modes for tanks, including illustrations of actual tank failures. The section discusses a range of factors that can lead to failure including defective material, use of incorrect equipment, and human error.

There is a brief section on control of documentation in Appendix 2.

CIRIA 598 is useful for drawing attention to examples of best practice in the integrity management of tank systems, and provides references to appropriate in-depth technical guidance. It would not be suitable as a stand-alone standard covering all aspects of the mechanical integrity management of atmospheric storage tanks.

API 2000: Venting Atmospheric and Low-Pressure Storage Tanks – Non-refrigerated and Refrigerated

The American Petroleum Institute Standard API 2000 provides thorough guidance on the effective normal and emergency venting of vapours from atmospheric storage tanks. The causes of overpressure and vacuum conditions that give rise to the requirement for venting provision are discussed. The standard then goes on to discuss the determination of venting requirements for specific circumstances. This includes the equations and calculations that enable the required vent sizes to be established.

Practical mechanical aspects of venting beyond the design stage are also included in the standard. The types of vent available and their suitability for normal and emergency venting use are discussed. Guidance is provided on the installation and maintenance of vents and the verification of set-pressure on emergency relief valves. Experimental and theoretical methods for determining the capacity of vents are presented. An appendix is provided describing the operating characteristics of various venting devices.

API 2000 provides excellent in-depth coverage of a specific issue in tank integrity management, namely venting provision. As such it is suitable as a standard for this issue, but would obviously not be suitable as a standard to cover all aspects of the mechanical integrity management of atmospheric storage tanks.

API 653: Tank Inspection, Repair, Alteration, and Reconstruction

API 653 is the companion standard to API 650 and is intended to cover all aspects of inspection, repair, alteration and reconstruction of tanks built to the API standard 650 and its predecessor 12C. The standard provides in-depth coverage of the various mechanical integrity aspects of atmospheric storage tanks.

Tank inspection methods are described in the standard, including internal inspection and alternatives to internal inspection. Guidance on inspection frequencies, and the considerations to be taken into account when determining these frequencies are discussed. This includes an overview of the risk-based approach to inspection. Comprehensive inspection checklists for in-service and out-of-service inspection are presented, as is information on the certification of inspectors. The selection of appropriate non-destructive test examination methods is covered in a comprehensive appendix.

Examples are provided to illustrate how to interpret the results obtained from inspection, including any necessary equations and calculations. Information on the allowable extent of ageing to enable continued service is given, which includes minimum thicknesses for various tank components, limits of acceptable shell distortion, corrosion limits, and weld condition, amongst others. Brittle fracture is considered in some detail, and a decision tree is provided to enable judgements on suitability for continued service to be made. The text describes the failure modes for each region of the tank, with methods for evaluating and detecting failure or deterioration.

The repair of tanks is outlined with detail provided on acceptable types of repair and procedures for carrying out the repairs. Rules on component replacement, particularly regarding roofs and roof seals, are set out. The tests required following repairs are described, including the circumstances in which tanks can be exempted from certain tests. Required qualifications for welding operators are identified

Change of service of tanks is discussed, with sections on operation at different pressures, elevated temperatures, and temperatures lower than the original design temperature. The venting considerations that must be taken into account when considering a change of service are outlined.

In addition to change of service aspects, the modification of tank structures is also covered. This includes the raising of shell height and the retrospective fitting of tank bottom telltale leak detectors. The circumstances in which hot taps can be carried out are detailed, and hot tap procedures are described.

Detailed information on the reconstruction of tanks is included, which discusses suitable methods for the dismantling of tanks as well as design and reconstruction aspects. The reconstruction section includes information on welding and dimensional tolerances, and the provision of approved marking and nameplates on reconstructed tanks.

Aspects of documentation management are touched upon, including the requirement to keep maintenance records.

API 653 provides excellent coverage on testing, inspection and maintenance to complement the information on design and construction provided in API 650.

BS EN 14015: Specification for the Design and Manufacture of Site Built, Vertical, Cylindrical, Flat-bottomed, Above Ground, Welded, Steel Tanks for the Storage of Liquids at Ambient Temperature and Above

BS EN 14015 covers all aspects relevant to the design of atmospheric storage tanks, which includes coverage of all the aspects listed below.

- Information required to be exchanged between customer and contractor
- Design pressure
- Materials specification – steel and weld materials
- Tolerances
- Design loads
- Design of tanks components: bottoms, shells, stiffening rings and wind girders, roofs, floating roof seals, attachments
- Electrical earthing
- Shell and roof openings
- Venting requirements

Coverage of design aspects is particularly good in a number of areas, including:

- tank shells (permitted stresses, minimum thicknesses, thicknesses of courses, joint configurations, calculating shell thicknesses based on loads);
- stiffening rings and wind girders (configurations, requirements, and calculations);
- shell and roof openings (nozzles, manways, detailed specifications on maximum sizes, configurations, weld details); and
- attachments (wind girders, stairs, walkways, permanent and temporary attachments).

The document details the standards that apply in tank construction, including the procedure for welding and the approval of welders, detail of weld requirements, post-weld heat treatment, and radiography and ultrasonic inspection of welds. There is good coverage of post-construction testing, including the various inspection methods and test procedures available. The focus here is on post-construction testing rather than inspection and testing from the perspective of ongoing mechanical integrity when operating.

The annexes to the standard give further detail on a number of issues, including:

- local climatic and geological factors that should be considered during design, including seismic provisions;
- in-depth coverage on floating covers, floating roofs, and rim seals for floating roofs; and
- vent system requirements, types of vent, and flow rate calculations.

BS EN 14015 is a standard providing good coverage of design and construction issues relevant to the mechanical integrity of atmospheric storage tanks. The standard does not purport to inform tank users on issues regarding inspection, maintenance and other issues relevant to continuing operation, nor on the issue of decommissioning. Some of the detail provided in the standard on post-construction inspection and testing will be relevant to the issue of continuing integrity, but clearly the standard does not attempt to provide overarching coverage of the full lifecycle of mechanical integrity management for tanks.

BS 2654: Specification for Manufacture of Vertical Steel Welded Non-refrigerated Storage Tanks with Butt-welded Shells for the Petroleum Industry

This standard has been superseded in the UK by BS EN 14015, which appears to have much in common with its British predecessor. BS 2654 covers the design and construction of bulk storage tanks, and this includes discussion of the items listed below.

- Information required to be exchanged between customer and contractor
- Design conditions, including design pressure and design metal temperature
- Specification of materials, especially specifications for steel used in construction
- Design of tank components: shell, bottom, fixed and floating roofs
- Venting requirements
- Anchoring of tanks
- Attachments and openings, including manholes and nozzles, with details on reinforcement at attachment sites
- Detailed diagrams of weld configurations, and information on welding processes, procedures, and approval of welders. Post-weld inspection, including the extent of radiography required, the procedure for conducting radiographic investigations, and the approach to interpreting the results
- Post construction inspection and testing
- The provision of tank insulation

Like BS EN 14015, the standard goes on to provide appendices giving additional information on some of the aspects discussed in the main text. This includes details of tank foundations, recommendations for the design and application on insulation, and venting systems.

BS 2654 provides good coverage on the design and construction requirements for bulk storage tanks. The standard has been superseded by BS EN 14015, which provides further in-depth coverage of design and construction issues. The standard clearly does not set out to provide guidance on issues of mechanical integrity other than those stemming from the design and construction stages, though some of the information on inspection is useful regarding continuing integrity issues.

ISO 28300: Petroleum, Petrochemical and Natural Gas Industries – Venting of Atmospheric and Low-pressure Storage Tanks

This ISO standard was developed from the 5th Edition of API 2000 (see above). ISO 28300 is intended to be identical to the 6th Edition of API 2000 when this is published. Much of the discussion of API 2000 above is therefore relevant to ISO 28300.

The standard aims to provide in-depth guidance on the issue of normal and emergency venting provision for storage tanks. The causes of overpressure or vacuum that lead to the requirement for venting are discussed. Detailed information on how to determine venting requirements is provided, giving advice on the calculation of flow rates, outbreathing and inbreathing, and emergency venting requirements. Specifications for vents are given, as is information on the installation and testing of vent devices.

The appendices to the standard give an alternative calculation of normal venting requirements and outline the basis for the equations used in vent sizing calculations. The operating characteristics of venting devices are also outlined.

ISO 28300 provides the information required to ensure effective normal and emergency venting of bulk storage tanks. The standard focuses on this issue exclusively, so this would have to be only one of a set of standards recommended for ensuring the mechanical integrity of storage tanks, rather than a single recommended standard on the issue.

API 620: Design and Construction of Large, Welded, Low-pressure Storage Tanks

API 620 focuses on the design and construction elements of tank integrity and covers low-pressure storage tanks with "a single vertical axis of rotation". Low pressure can include atmospheric pressure. The standard therefore technically includes large, cylindrical, vertical tanks as well as tanks such as spherical tanks. Primarily though, API 650 is the standard that is most appropriate to the types of tanks of interest in this review.

The standard details all the requirements relevant to the design, including allowable stresses, corrosion allowances, and designs of bottoms, walls and roofs. Specifications are given for the materials permitted for use in the construction.

Post-construction treatment and testing is specified, with detail on heat treatment for relieving stress and radiographic and ultrasonic testing of welds. Hydrostatic and pneumatic tests are also discussed.

The appendices to the standard give further detailed information on a number of topics, including example calculations, designs to take account of seismic conditions, details on tank foundations, and non-destructive examination requirements.

Overall, API 620 is a useful standard for design and construction of storage tanks, but API 650 is generally more detailed and presents a more rigorous treatment. It would therefore be a more appropriate standard for the types of tank covered by API 650.

API 2610: Design, Construction, Operation, Maintenance, and Inspection of Terminal & Tank Facilities

This standard aims to cover all aspects of terminal and tank facilities, so it is not just limited to the mechanical integrity of tanks. The coverage of each item is therefore brief and quite general, with references to more in-depth documents given in the text.

The section of the standard on tanks provides references to the recommended API standards for tank design and construction, as well as standards from API and Underwriters Laboratory directed towards inspection, repair and maintenance.

API 2610 covers tanks selection criteria, release prevention and detection, and tank openings and attachments. The standard contains quite a lot of detail on corrosion control through coating, both internal and external. There is some detail on inspection, but the list of inspection requirements is not particularly comprehensive.

API 2610 is intended to give an overview to multiple aspects of terminal and tank facility operation, and provides references to the detailed standards that are required for practical management of the mechanical integrity of storage tanks.

HSE SPC/Tech/Gen/35: Integrity of Atmospheric Storage Tanks

This document is a semi-permanent circular aimed at HSE specialist inspectors with an interest in ensuring the mechanical integrity of atmospheric storage tanks. The guide presents collated findings from a range of inspections carried out at tank facilities, and provides examples of best practice observed during these inspections.

The circular emphasises the need for organisations to have written inspection schemes for tanks, and to keep good records of inspections and maintenance.

There is good background information on damage mechanisms, including corrosion, erosion, fatigue, chemical attack, mechanical damage, and defects in original manufacture and repair.

The document provides information on inspection methods, and the situations in which each method might be used. The document does not aim to provide a comprehensive guide to how to conduct these inspections, but aims to raise awareness on the suitability of various techniques.

The main focus of this document is to raise awareness of mechanical integrity issues regarding storage tanks, and to highlight observed good and best practice in relation to this. The document provides references to the standards and other information that are necessary in order to effectively manage tank integrity.

HSG 176: The Storage of Flammable Liquids in Tanks

This HSE guidance provides information on the design, construction, operation and maintenance of tank facilities for the storage of flammable liquids. The guide aims to educate operators on the steps they need to take in order to ensure that the safety management of their facilities meets the standards required by law.

The guide discusses relevant legal requirements and provides advice on risk assessment, fire and explosion hazards, hazardous area classification and control measures.

On the specific issue of the mechanical integrity of tanks, HSG 176 provides information on the location and layout of tanks, with recommendations on separation distances. The guide emphasises the importance of designing tanks according to an accepted standard, and gives references to appropriate standards. There are brief notes on vent sizing, tank foundations, tank anchoring, electrical earthing, and weather protection.

The modification and decommissioning of tanks is briefly discussed, but not in technical detail. The information is more general, and emphasises the need for risk assessment and safe operation.

HSG 176 is a useful guide for operators as it informs them of the sorts of things they need to consider to comply with the law, but does not offer sufficient technical detail for this to be the only publication consulted on the issue. The publication instead intends to raise awareness, and to point users to the other, more technically detailed, sources of information of relevance, particularly accepted standards.

EEMUA 180: Guide for Designers and Users on Frangible Roof Joints for Fixed Roof Storage Tanks

The sole focus of EEMUA 180 is the steps necessary for ensuring that frangible roof joints on fixed roof tanks are effective. In practice this means making sure that the weakest part of the tank structure is the frangible joint itself.

The document provides a brief description of tank failure modes with examples of failures that have occurred at points other than the frangible joint. It then goes onto provide detailed information on ensuring that frangible connections are effective, which covers issues such as the strength of the shell-bottom connection as well as details of the frangible connection itself. The modification of existing tanks lacking a frangible connection is also covered.

EEMUA 180 provides good coverage of one specific issue relevant to the mechanical integrity of storage tanks.

EEMUA 183: Guide for the Prevention of Bottom Leakage from Vertical, Cylindrical, Steel Storage Tanks

This publication focuses on one of the most vulnerable parts of tanks - the tank bottom. The standard provides figures for the probability of tank bottom leakage correlated with age of tank, and classifies the different types of tank bottom based on their inherent integrity. It also provides an overview of legislative trends for the USA and Germany.

Technical detail is provided on tank foundations and tank bottom design. The main causes of bottom leakage are described, and some retirement criteria for bottom plates based on thickness are given. These criteria do not invoke detailed calculations. Coverage of inspection techniques and inspection intervals and record keeping is included.

Useful flow charts are provided for users to aid in decision-making regarding repairs.

EEMUA 183 provides coverage of tank bottom leakage, with some aspects covered in substantial technical detail. Other topics are covered briefly, with references to appropriate standards providing more in depth coverage.

API 12B: Specification for Bolted Tanks for Storage of Production Liquids

This American Petroleum Institute standard focuses on the requirements for the design and construction of bolted tanks for storage of liquids. The main focus of the document is on the design of the tanks in terms of the layout of individual plates, the specification of materials for use in the plates, and the details of bolting systems used in erection of the tanks. The standard also gives recommended vent sizes for normal and emergency venting.

API 12B is only suitable for bolted storage tanks, and is not appropriate as a standard for tanks of welded construction. The level of technical detail in API 12B is not as great as that provided in the other construction standards, such as API 650 and BS EN 14015.

API 12R1: Recommended Practice for Setting, Maintenance, Inspection, Operation, and Repair of Tanks in Production Service

This API publication is a statement of recommended practice rather than a standard, and gives guidance on inspection and maintenance issues relating to tanks designed to API 12B, 12D, 12F, and 12P. The scope section states that the publication is for application to tanks in on-land production, and is not suitable for refineries, petrochemical plants, marketing bulk stations, or pipeline storage facilities; users are directed to API 650 (design and construction) and API 653 (inspection and maintenance standard for API 650 and API 12C tanks).

The standard contains a section dedicated to issues relevant to tank integrity, which includes hydrotesting, cathodic protection, internal coating, and vapour tightness. There follows a section on safe operation, which discusses the importance of matching liquid flow rates to the venting capacity of the tank in order to prevent tank collapse.

The importance of an ongoing inspection programme in ensuring continuing integrity of tanks is emphasised in the section on inspection. Guidelines on inspection frequencies are given, along with information on the issues that should be considered during internal and external inspection. The issue of roof corrosion receives particular attention. The factors that should be considered when assessing the fitness of a tank for continued service are discussed.

The section on repairs and maintenance pays particular attention to shell plate replacement, non-welded patching, and welding. Alteration of tank shell height is discussed. Brief mention is made of hot taps, and the reader is directed to API publication 2009 for the preparations and procedures to follow in this operation. There is also a section discussing the reconstruction of previously dismantled tanks.

The appendices to the standard discuss qualifications for inspectors, vent sizing and related calculations, shell corrosion and brittle fracture, minimum thickness calculations, and give sample inspection checklists.

API 12R1 is specifically directed towards the maintenance of tanks built to API 12B, 12D, 12F and 12P. These construction standards are not appropriate for large, welded, vertical, cylindrical storage tanks most likely to be in service at Buncefield-type facilities, for which API

653 is the appropriate maintenance standard and API 650 (or predecessor API 12C) the appropriate design standard. As such, API 12R1 is not suitable as the recommended standard for bulk atmospheric storage tanks of welded construction.

API RP 575: Guidelines and Methods for Inspection of Existing Atmospheric and Low-pressure Storage Tanks

API RP 575 is not a standard, but a recommended practice publication intended to supplement the inspection and maintenance standard API 653 (which outlines the minimum requirements for operators of API standard vessels). API RP 575 and the companion standard API 653 are appropriate to the inspection and maintenance of tanks built to API 12A, 12C, 620, and 650.

The publication gives good illustrations of various tank types, with substantial coverage of floating roof types and roof sealing arrangements.

There is a good discussion of the types of corrosion, ageing and failures that affect tanks, with photographs of representative cases.

The recommended practice gives guidance on inspection frequency, including condition-based inspection scheduling and risk-based inspection methods. The areas of tanks that should be inspected are discussed, and this coverage includes in-service and out-of-service inspections. There is good coverage on the internal inspection of tanks, with emphasis on the areas of the inside to which particular attention should be paid.

Inspection and test methods are described, which include hydrotest, various methods for bottom leak detection, and non-destructive examination methods.

There is brief coverage of repairs and alterations from the perspective of the integrity of the repair. The publication advises repair to the original construction standard, and gives some detail on weld repair, bottom repair, and shell and rood repair, including temporary soft patch repairs to leaking roofs.

Appendix B to the publication gives detailed guidance on the use of similar service evaluations, and provides tables and advice on what to consider. It is the only standard covered by this review to give detailed information on similar service evaluations.

API RP 575 is very useful when used in conjunction with the associated standard API 653. It is not intended to be a stand-alone guide to inspection and maintenance, and should not be used as such. It adds further detail to API 653, and refers the reader to API 653 for most of the detailed technical guidance required.

2.3 DISCUSSION AND CONCLUSIONS

It is apparent from the documents reviewed that there is no one standard that can be considered suitable for recommendation as an overarching standard on the issue of mechanical integrity management of bulk storage tanks. The publications reviewed tend to give either general, brief overview guidance across a spectrum of issues, or specific, detailed guidance on a particular topic (for example, API 2000 on vent sizing) or group of topics (for example API 653 on inspection and maintenance).

If a recommendation is to be made to operators regarding the minimum standards acceptable for ensuring effective mechanical integrity management of bulk storage tanks, this will need to take the form of guidance identifying a collection of standards that, when taken together, encompass all the relevant issues.

The standards that are probably of most interest in each area relevant to mechanical integrity management are highlighted below.

Design and construction

BS EN 14015 and API 650 provide the most up-to-date and in-depth guidance on design and construction elements.

Inspection/ maintenance/repair

API 653 and the companion recommended practice API RP 575, when taken in conjunction, provide good detail on inspection, maintenance and repair. EEMUA 159 volumes 1 and 2, when taken together, also give good detail on these elements.

Single-issue standards

- **Vents:** Vent sizing is covered in detail by the dedicated standard ISO 28300. The coverage in this standard is slightly more up-to-date than that in the equivalent API 2000, which is due to be harmonised with ISO 28300 at the next edition.

- **Frangible roofs:** For good information on ensuring the effectiveness of frangible roof joints, EEMUA has issued EEMUA 180.

- **Bottom leakage:** EEMUA 183 provides extensive guidance on the prevention of bottom leakage.

Overview publications

In terms of providing a brief overview of the various issues relevant to integrity management, and directing readers to more detailed coverage of individual issues through references, CIRIA 598 is a good publication. The HSE guidance booklet HSG 176 is very general, but does provide a specific UK-focus.

3 WIDER INTEGRITY MANAGEMENT ISSUES

Searches were conducted through the IHS database Standards Expert in order to identify any international or national standards or guidance covering wider integrity management issues. The focus of this search was the identification of standards directed towards engineering records management and competency assurance. Details of the search strategies employed are provided in Appendix 1. The standards identified through these searches are listed in Table 9, and are grouped according to subject focus.

Table 9 Standards pertaining to wider integrity management issues

Standard	*Title*
Quality management (petroleum / chemical sector specific)	
ISO/TS 29001	Petroleum, Petrochemical and Natural Gas Industries – Sector Specific Quality Management Systems – Requirements for Product and Service Supply Organisations
API SPEC Q1	Specification for Quality Programs for the Petroleum, Petrochemical and Natural Gas Industry
Facility management (managing loss of containment risk)	
API PUBL 353	Managing Systems Integrity of Terminal and Tank Facilities – Managing the Risk of Liquid Petroleum Releases
Non-destructive testing	
ASNT CP-189	Qualification and Certification of Non-destructive Testing Personnel
ASTM E 1212	Standard Practice for Quality Management Systems for Non-destructive Testing Agencies
BS EN 4179	Qualification and Approval of Personnel for Non-Destructive Testing
Mechanical equipment quality	
API RP 683	Quality Improvement Manual for Mechanical Equipment in Petroleum, Chemical, and Gas Industries
Welding	
AWS B5.16	Specification for the Qualification of Welding Engineers
Maintenance / engineering records	
BS EN ISO 14224	Petroleum and Natural Gas Industries – Collection and Exchange of Reliability and Maintenance Data for Equipment
BS ISO 24517	Document Management – Engineering Document Format Using PDF
Generic (non-sector specific) quality management	
ISO 9000 series	ISO series on Quality Management

Standard	*Title*
Generic (non-sector specific records management)	
ISO 15489-1 & ISO TR 15489-2	Information and Documentation – Records Management

The official synopsis for each of the above listed standards, where available, is reproduced below.

Quality management (petroleum / chemical sector specific)

ISO/TS 29001

This Technical Specification defines the quality management system requirements for the design, development, production, installation and service of products for the petroleum, petrochemical and natural gas industries.

API SPEC Q1

This Technical Specification defines the quality management system for product and service supply organisations for the petroleum, petrochemical and natural gas industries.

Boxed text is original ISO 9001:2000 text unaltered and in its entirety. The petroleum, petrochemical, and natural gas industry sector-specific supplemental requirements are outside the boxes.

Facility management (managing loss of containment risk)

API PUBL 353

Although the risk management principles and concepts in this document are universally applicable, this publication is specifically targeted at integrity management of aboveground liquid petroleum storage facilities. The applicable petroleum terminal and tank facilities covered in this document are associated with distribution, transportation, and refining facilities as described in API Std 2610 and API Publ 340.

This document covers the issues of overall risk management, risk assessment, risk ranking, risk mitigation, and the performance measures applicable to an overall integrity management program. The appendices include two possible methodologies for conducting a risk assessment and a workbook that can be used to perform the risk assessment method outlined in Appendix A.

Non-destructive testing

ASNT CP-189

This American National Standard builds upon the success of *Recommended Practice No. SNT-TC-1A* by providing comprehensive minimum requirements for personnel certification. Included are requirements for NDT instructors and employer certification of Level I, II, and III personnel, and a requirement for the ASNT NDT Level III certification of Level III personnel. Includes training outlines for 11 NDT methods, including Infrared and Thermal Testing. This standard has been approved by the American National Standards Institute (ANSI).

ASTM E 1212

This practice covers general requirements for the establishment and maintenance of a quality management system for agencies engaged in non-destructive testing (NDT).

This practice utilises criteria contained in American National Standard ANSI/ISO/ASQ Q9001-2000, Quality management systems - requirements.

This practice recognises the importance of establishing minimum safety criteria.

BS EN 4179

This standard establishes the minimum requirements for the qualification and certification of engineering personnel involved in non-destructive testing (NDT). Non-destructive testing is the branch of engineering concerned with all methods of detecting and evaluating flaws in materials. Flaws can affect the serviceability of the material or structure, so NDT is important for guaranteeing safe operation, quality control and assessing plant life. Flaws may be cracks or inclusions in welds and castings, or variations in structural properties that could lead to loss of strength or failure in service.

This standard contains detailed requirements for the applicable training, experience, and examination for the following common NDT methods:

Liquid penetrant (PT); Magnetic particle (MT); Eddy current (ET); Ultrasonic (UT); and Radiography (RT).

These requirements include qualifications, training, experience and examinations for personnel performing NDT in the aerospace manufacturing, service, maintenance and overhaul industries.

This standard applies to personnel using NDT methods to test and/or accept materials, products, components, assemblies or sub-assemblies. It also applies to those individuals directly responsible for the technical adequacy of the NDT methods used, as well as personnel performing external NDT technical audits or providing technical NDT training.

Mechanical equipment quality

API RP 683

This recommended practice provides guidelines for improving the quality of mechanical equipment. It is intended to mutually benefit users, contractors, and suppliers and facilitate improved relationships between them by promoting trust, teamwork, and communication. It is not intended to determine certification to or compliance with a particular quality system specification.

A three-part approach for improving the quality of mechanical equipment is described in this recommended practice, consisting of (a) the traditional methods used to help assure quality; (b) techniques that can be used to identify those suppliers who have quality systems so effective that intense user involvement is unnecessary: and (c) suggestions on how users, contractors, and suppliers can work together to improve quality.

Section 2 describes methods by which users pre-qualify suppliers, prepare comprehensive specifications, conduct communication meetings, audit designs, institute manufacturing quality surveillance, sponsor intensive factory testing, and conduct equipment inspections at the site prior to start-up.

Section 3 (along with Appendix A) contains guidelines for evaluating the type of quality system and effectiveness of the quality system used by a supplier. Emphasis is placed on the commitment of management to the quality system, the structure of the system, relationships with sub-suppliers, training, evidence of continuous quality improvement throughout the organization, and the supplier's performance on recent projects.

Section 4 addresses ways that users, contractors, and suppliers can all work together to improve their quality systems. It includes such topics as uniformity and joint development of equipment requirements, risk sharing, communication, training, and constructive feedback. Users are encouraged to reduce the use of lengthy supplemental specifications and rely more on API standards and data sheets.

This recommended practice is complementary to the referenced standards, but it goes beyond them to address the development and evaluation of systems incorporating continuous quality improvement. This recommended practice is specifically applicable to the mechanical equipment industry.

Welding

AWS B5.16

This specification establishes the requirements for qualification of welding engineers employed in the welding industry. The minimum experience, examination, application, qualification, and requalification requirements and methods are defined herein. This specification is a method for engineers to establish a record of their qualification and abilities in welding industry work such as development of procedures, processes controls, quality standards, problem solving, etc.

Maintenance/engineering records

BS EN ISO 14224

No synopsis available.

BS ISO 24517

Specifies the use of the Portable Document Format (PDF) for the creation of documents used in engineering workflows.

Generic (non-sector specific) quality management

ISO 9000 series

No synopsis available.

Generic (non-sector specific) records management

ISO 15489-1 & ISO TR 15489-2

ISO 15489 provides guidance on managing records of originating organizations, public or private, for internal and external clients.

ISO TR 15489-2 is an implementation guide to ISO 15489-1 for use by record management professionals and those charged with managing records in their organisations. It provides one methodology that will facilitate the implementation of ISO 15489-1.

3.1 DISCUSSION

It is apparent from the results of the searches that there are relatively few standards specifically addressing the issues of engineering records management or competency assurance.

A couple of the standards identified in Table 9 are not specific to particular disciplines, but apply across a broad range of industries. Perhaps the most well known example of this type is the ISO 9000 series on quality management. In fact, several of the more sector-specific standards listed above are based upon the ISO 9000 series. These include ISO/TS 29001, API SPEC Q1, and ASTM E 1212.

Two standards were identified that are directed towards quality management in the petroleum or chemicals sectors: ISO/TS 29001 and API SPEC Q1. Both of these are geared towards ensuring quality in products and services supplied to the industry. In the case of API SPEC Q1 this includes the manufacture of products to API standards, and could therefore cover the issue of initial mechanical integrity.

API PUBL 353 is targeted at the integrity management of above ground liquid petroleum storage facilities, and as such is clearly relevant to the issues of interest in this report.

A number of standards relating to non-destructive testing have been identified: ASNT CP-189, ASTM E 1212, and BS EN 4179. The focus of ASTM E 1212 is the quality management of agencies that engage in non-destructive testing. The other two standards focus on the testing itself, in particular the certification of the personnel involved in conducting the tests.

API RP 683 is concerned with ensuring the quality of mechanical equipment. The standard discusses ways identifying suppliers with effective quality systems, and how suppliers, users, and contractors can work together to improve quality.

The standard on welding, AWS B5.16 is an American Welding Society standard directed towards qualification requirements for welding engineers.

BS EN ISO 14224 sets out standards for the collection and exchange of reliability and maintenance data. The standard is directed specifically at the petroleum and natural gas industries, and will clearly be relevant to continuing mechanical integrity. The other standard relating to record management, BS ISO 24517, is focused upon the use of PDF document formats in creating engineering workflow documents.

The ISO 9000 series of standards relate to quality management systems in general, and as such are applicable across a wide range of industries. The primary aim of this series of standards is the implementation of quality procedures to ensure customer satisfaction.

The ISO standard 15489-1 and the associated document ISO TR 15489-2 provide guidance on the management of records within organisations. They provide generic guidance, and are not specifically directed towards the management of engineering records.

In addition to the standards discussed above, it should be noted that some of the standards reviewed in Section 2 touch on the issues of competency assurance and records management. For example, BS EN 14015, BS 2654, and API RP 575 all include sections on documentation requirements for construction. EEMUA 159, API 653, HSG 176, EEMUA 183 and API RP 575 all contain sections on inspection records and documentation. API 653 and API RP 575 discuss the keeping of maintenance records. The competency of personnel is touched upon in API 653, API 620 and API 12R1.

APPENDIX 1

A1.1 IHS DATABASE SEARCHES

Searches to identify standards of potential relevance were conducted through the online IHS Standards Expert database. The following keyword strategies were employed (* indicates any ending):

Bulk AND storage

Atmospheric AND (storage OR tank* OR vessel*)

Tank* AND farm*

Petrol* AND (stor* OR tank* OR vessel*)

Record* AND (engineer* OR mechanical* OR manag*)

Quality* AND (manag* OR engineer*)

Integrit* AND manag*

Engineer* AND (qualification* OR competen* OR training* OR accredit* OR certif*)

Competen* AND assurance*

A1.2 EXCLUSIONS

A number of standards were unavailable for review at the time of this study. Details of these are given in Table A1. A list of standards that were identified, but not selected for review, is given in Table A2. This includes the rationale for not reviewing these documents.

Table A1 Standards unavailable for review

Standard	*Title*	*Year*	*Publishing body*	*Country*	*Status*
UL 142	Steel Aboveground Tanks for Flammable and Combustible Liquids		Underwriters Laboratory	USA	Current
	Official Scope UL 142 1.1 These requirements cover steel primary, secondary and diked type atmospheric storage tanks intended for non-corrosive, stable flammable and combustible liquids that have a specific gravity not exceeding 1.0 in aboveground applications. 1.1.1 Each tank type may be fabricated in a combination of various shapes (cylindrical, rectangular or round) and orientations (horizontal, vertical) with or without multiple compartments, as covered in this Standard. 1.2 These tanks are intended for installation and use in accordance with the Flammable and Combustible Liquids Code, NFPA 30; the Standard for Installation of Oil-Burning Equipment, NFPA 31; the Motor Fuel Dispensing Facilities and Repair Garages, NFPA 30A; the Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines, NFPA 37; the Uniform Fire Code, NFPA 1; and the International Fire Code published by the International Code Council. 1.3 The tanks covered by these requirements are fabricated, inspected and tested for leakage before shipment from the factory as completely assembled vessels. 1.4 These requirements do not apply to tanks covered by the Specification for Field-Welded Tanks for Storage of Production Liquids, API 12D; and the Specification for Shop-Welded Tanks for Storage of Production Liquids, API 12F. 1.5 Deleted December 15, 2007. 1.6 These requirements do not cover special evaluations for resistance to hurricanes, tornadoes, earthquakes, floods, or other natural disasters; or resistance to vehicle impact. 1.7 These requirements do not cover portable tanks intended for transporting flammable or combustible liquids (such as shipping containers), or mobile use applications (such as mounted on a trailer). These types of products are covered by separate UN, DOT, or equipment product standards.				
CEN/TC 265	Site Built Metallic Tanks for the Storage of Liquids				
EEMUA 154	Guidance to Owners on Demolition of Vertical Cylindrical Steel Storage Tanks and Storage Spheres	2002	The Engineering Equipment and Materials User Association	UK	Current

Standard	*Title*	*Year*	*Publishing body*	*Country*	*Status*
	Abstract EEMUA 154 The publication covers the demolition of tanks built to BS 2654, API 650, or similar; of refrigerated tanks to BS 7777, API 620, or similar and of (LPG or ammonia) column-supported storage spheres built to recognised pressure vessel codes such as BS PD 5500 and ASME VIII. Reference is also made in the text to UK statutory requirements governing such demolition work. The publication is well illustrated with diagrams and photographs.				
IP TP 29	Internal Floating Roods for Oil Storage Tanks		Institute of Petroleum	UK	
	Abstract IP TP 29 Specifies minimum requirements for the materials, design, construction, testing, operation and maintenance of internal floating roofs, applicable to both new and retrospective installations.				

Table A2 Standards not selected for review

Standard	*Title*	*Year*	*Publishing body*	*Country*	*Status*	*Rationale for not reviewing*
AS 4971	Inspection and Integrity Monitoring of Large Steel Vertical Petroleum Storage Tanks	2008	Standards Australia	Australia	Current	Australian standard unlikely to be particularly relevant to UK
TSE TS 4943	Safety Standards in Crude Oil and Petroleum Storage Tank Farms	1986		Turkey	Current	Turkish standard unlikely to be particularly relevant to UK Standard relatively old
API PUBL 937	Evaluation of Design Criteria for Storage Tanks With Frangible Roof Joints	1996	American Petroleum Institute	USA		Not a standard – an evaluation of design criteria
BS 5493	Code of Practice for Protective Coating of Iron and Steel Structures Against Corrosion	1977	British Standards Institution	UK	Current	Not aimed specifically at tanks – general guidance on coating of iron and steel structures
API 12C	Welded Oil Storage Tanks	1958	American Petroleum Institute	USA	Superseded by API 650	Not current standard – superseding standard reviewed instead
EN 12285-2	On above ground tanks	2005	European Committee for Standardization	Europe	Current	Relates to shop-built and horizontal tanks only. Not relevant to Buncefield-type tanks
DIN 4119	Above-ground cylindrical flat-bottom tank structures of metallic materials	1980	Deutsches Institut für Normung	Germany		German standard
ASTME E 1930	Standard Practice for Examination of Liquid-filled Atmospheric and Low-pressure Metal Storage Tanks Using Acoustic Emission	2007	ASTM	USA		Very specific standard directed towards the implementation of a particular examination technique

Standard	*Title*	*Year*	*Publishing body*	*Country*	*Status*	*Rationale for not reviewing*
NATO STANAG 3609	Tanks, Petroleum Fuel and Lubricants, Operating and Bulk Storage, Minimum Frequency for Inspection and Cleaning		NATO			Standard specific to NATO – more widely available national standards reviewed instead
API BULL 2521	Use of Pressure-vacuum Vent Valves for Atmospheric Pressure Tanks to Reduce Evaporation Loss	1966	American Petroleum Institute	USA	Information only – not a standard	Of more relevance to the issue of vapour loss rather than mechanical integrity of tanks *per se*
API IRE C13	Guide for Inspection of Refinery Equipment – Atmospheric and Low-pressure Storage Tanks		American Petroleum Institute	USA	Superseded by API RP 575	Superseding standard API RP 575 reviewed instead
API PUBL 334	A Guide to Leak Detection for Aboveground Storage Tanks	1996	American Petroleum Institute	USA	Current	Concentrates specifically on the methods for leak detection, rather than mechanical integrity of tanks *per se*
CGSB 85-GB-12M	Painting bulk storage tanks (above ground)					Specific to painting practices, rather than mechanical integrity of tanks *per se*
UFGS-09 97 13.15	Epoxy/fluoropolyurethane Interior Coating of Welded Steel Petroleum Fuel Tanks					Specific to coating practices, rather than mechanical integrity of tanks *per se*
UFGS-09 97 13.17	Three Coat Epoxy Interior Coating of Welded Steel Petroleum Fuel Tanks					Specific to coating practices, rather than mechanical integrity of tanks *per se*

Standard	*Title*	*Year*	*Publishing body*	*Country*	*Status*	*Rationale for not reviewing*
UFGS 09970	Interior Coating of Welded Steel Petroleum Fuel Tanks					Specific to coating practices, rather than mechanical integrity of tanks *per se*
UFGS 09970N	Interior Coating of Welded Steel Petroleum Fuel Tanks					Specific to coating practices, rather than mechanical integrity of tanks *per se*
UFGS 09973	Interior Coating of Welded Steel Petroleum Fuel Tanks					Specific to coating practices, rather than mechanical integrity of tanks *per se*

4 REFERENCES

1. Buncefield Standards Task Group Initial Report [http://www.hse.gov.uk/comah/buncefield/bstg1.htm]

2. COMAH Competent Authority Policy – Containment of Bulk Hazardous Liquids at COMAH Establishments, Health and Safety Executive, Environment Agency, Scottish Environment Protection Agency, 2008

3. Safety and Environmental Standards for Fuel Storage Sites, Buncefield Standards Task Group, Final Report, 2008 [http://www.hse.gov.uk/comah/buncefield/bstgfinalreport.pdf]

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Mechanical integrity management of bulk storage tanks

Review of standards

Following the Buncefield incident the importance of preventing loss of containment from bulk storage tanks has come to the fore. A significant factor in ensuring contained fluids are not accidentally released is the continuing mechanical integrity of the tank structure. With this in mind, the joint industry/ Competent Authority Process Safety Leadership Group has set up a working group to establish agreed industry standards for bulk storage tank integrity management.

The Health and Safety Laboratory was commissioned to produce a review of relevant published standards pertaining to the management of the mechanical integrity of bulk storage tanks. The findings from this review are reported here.

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