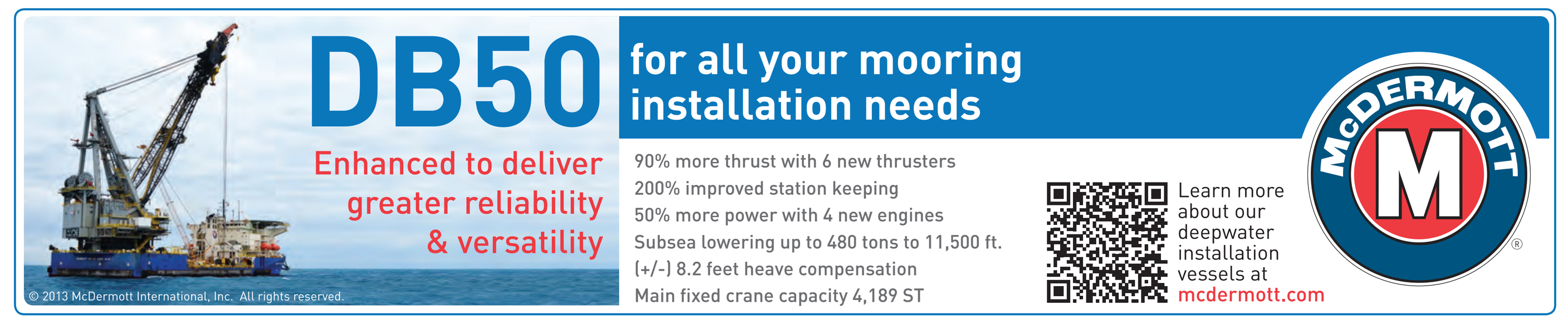

MOORING SYSTEMS FOR OFFSHORE FLOATING INSTALLATIONS

Trends & Technology

OCTOBER 2013

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TABLE 1 – ABBREVIATIONS

AP	Anchor Pile
C&P&W	Chain-Poly-Wire
C&W	Chain & Wire
CALM	Catenary Anchor Leg Mooring
C2R	Chain To Rope Connector
C2C	Chain To Chain Connector
DEA	Drag Embedded Anchor
Dr. P	Driven Pile
ET	External Turret
FPSO	Floating Production Storage & Offloading
HHP	High Holding Power
IT	Internal Turret
JSY	Jacket Soft Yoke
MODU	Mobile Offshore Drilling Unit
RTM	Riser Turret Mooring
R2R	Rope to Rope Connector
R2C	Rope to Chain Connector
SALM	Single Anchor Leg Mooring
SCM	Spread Catenary Mooring
SEA	Suction Embedded Anchor
SEMI	Semi Submersible
SEPLA	Suction Embedded Plate Anchor
SM	Spread Mooring
SP	Suction Pile
STM	Spread Taut Mooring
STP	Submerged Turret Mooring
TLP	Tension Leg Platform
VLA	Vertical Loaded Anchor

POSTER COLOR CODE KEY

The poster is divided into distinct sections and each section is marked by a background color. The color denotes the subject section. This color code is carried throughout the poster. Below are the color code designations for each of the themes.

- MOORING INTEGRITY
- MOORING EQUIPMENT
- MOORING LINES
- CONNECTORS
- MOORING ANCHORS
- MAP
- MOORING SYSTEM ELEVATIONS
- MOORING PATTERNS, TYPES, CONFIGURATIONS

TABLE 2 – OTHER OFFSHORE MOORING INFO. SOURCES

Recommended Papers, Manuals, and other documents for additional knowledge

PLANNING & INSTALLATION OF DEEPWATER MOORING SYSTEMS - VARIOUS PROJECTS

1	OTC 23223	2013	COOEC/COTEC	LIUHUA 11-1 FPS Mooring Upgrade
2	OCT 23083-MS	2012	LLOG/WHITEHILL/DELMAR	WHO DAT Project Mooring System
3	ISOPE I-10-470	2010	OFFSHORE OIL ENG. CO.	STP Moooring System in China
4	OTC 21018-MS	2010	InterMoor/ATP OIL & GAS	MIRAGE/TELEMARK MinDOC Mooring
5	OTC 18587-MS	2007	ENTERPRISE	INDEPENDENCE HUB Mooring Sys
6	OTC 17294-MS	2005	TECHNIP/DOVE MARINE	RED HAWK Spar Mooring System
7	OTC 16702-MS	2004	SHELL/HEEREMA	Na Kika DW Mooring Project

MOORING SYSTEM INSPECTION, TESTING, AND QUALIFICATION

1	OTC 24184-MS	2013	WELAPTEGA MARINE LTD.	Risk Based Inspection Plan
2	OTC 24080-MS	2013	SBM/LANKHORST	THUNDER HAWK Fatigue Testing
3	OMAE2012-84067	2012	InterMoor	Microbiological Corrosion
4	OTC 20779	2010	WELAPTEGA MARINE LTD.	In-Service Inspection

DESIGN & OPERATIONAL ISSUES

1	OTC 24214	2013	SEVAN MARINE	Op Experience with Cylindrical FPSO
2	OTC 23814-MS	2012	HEIDEMAN / BLUEWATER	Arctic Turret Mooring System
3	OMAE2011-49855	2011	SOFEC/DELFT UNIVERSITY	Squall Mooring Design
4	IDOTS D-09-004	2009	RESEARCH & DEV./SOFEC	Mooring in Harsh Environments

INTEGRITY & LESSONS LEARNED

1	OTC 24025-MS	2013	BP/TOTAL/SHELL	Mooring System Integrity Issues
2	OTC 24181	2013	GRANHERNE (KBR)	Lessons Learned from FPS Moorings
3	ISOPE I-12-563	2012	AMOG CONSULTING & Others	SCORCH JIP - Chain Corrosion
4	OTC 21012-MS	2010	SOFEC	Anchor Leg System Integrity
5	OTC 19198-MS	2008	STRESS ENGINEERING	Polyester Mooring Integrity
6	OTC 17499-MS	2005	NOBLE DENTON & Others	Floating Prod. Mooring Integrity JIP

SYNTHETIC FIBER MOORING SYSTEMS

1	OTC 23333-MS	2012	DYNEEMA/LANKHORST	HMPE Fiber for DW Mooring
2	OTC 22218	2011	STRESS ENG.	Evaluation of Advance Fibers
3	OTC 20838	2010	DEMLAR SYSTEMS	Fiber Mooring - Recent Experiences
4	OTC 20836-MS	2010	BP & Others	Changes in Update of AP RP 2SM
5	OTC 20155-MS	2009	SAMSON/DELMAR	Hurricane Proof Mooring System
6	OTC 18768-MS	2007	TENSION TECHNOLOGY	Polyester Mooring Line
7	OTC 17247-MS	2005	TECHNIP/KERR-MCGEE	RED HAWK System Design & Verif.
8	OTC16590	2004	BP/STRESS ENG/UNION	MAD DOG Polyester Mooring

Go to *www.onepetro.org* to order the **OTC** (Offshore Technology Conference), **SPE** (Society of Petroleum Engineers), and **ISOPE** (The International Society of Offshore and Polar Engineers) papers listed in Table 2.

OTHER SOURCES - BOOKS, E-BOOKS, WEB SITES

1. BOOK: DEEPWATER MMORING SYSTEMS - Concepts, Design, Analysis, and Materials Edited by Jun Zhang, Richard Mercier; 2003, 360 Pages
2. E-BOOK: JIP FPS MOORING INTEGRITY (2006), 313 Pages *www.hse.gov.uk/research/rrpdf/rr444.pdf*
3. E-BOOK: VRYHOF 2010 ANCHOR MANUAL; 188 Pages; *www.vryhof.com/anchor_manual.pdf*
4. E-BOOK: Classification of Mooring Systems for Permanent Offshore Units (April, 2012); 54 Pages *www.veristar.com/content/static/veristarinfo/images/4851.32.493NR_2012-04.pdf*
5. ON-LINE COURSE: Technology University of Delft (Netherlands); *http://ocw.tudelft.nl/courses/offshore-engineering/offshore-moorings/course-home/*
6. BOOK: The Univeristy of Texas Publication: Spread Mooring Systems, 2nd Edition; *http://www.utexas.edu/ce/petex/aids/pubs/spread-mooring/*
7. BOOK: Engineers Design Guide to Deepwater Fibre Moorings, By Oil Pub (2005)

MOORING STANDARDS

1. API Spec 2F - Mooring Chain (1997) - Currently in Revision
2. API RP 2I - In-service Inspection of Mooring Hardware for Floating Structures (2008).
3. API RP 2SK - Design & Analysis of Stationkeeping Sys. for Floating Str. (Add.2008)
4. API RP 2SM - Recommended Practice for Synthetic Fiber Ropes (Add. 2007) A new revision is currently in the Balloting Phase.
5. ISO 19901-7 Station-keeping systems for floating offshore structures (Rev)
6. ISO 19904-01 Floating offshore structures
7. 2GEO - Geotechnical Analysis of Mooring Anchors - Is a new standard in development.
8. 2MIM - Mooring Integrity Management. Is a new standard to be released.
9. DNV GL: http://www.dnv.com/resources/rules_standards/index.asp

CLASS SOCIETIES GUIDANCE DOCUMENTS ON MOORING SYSTEMS & INSTALLATION

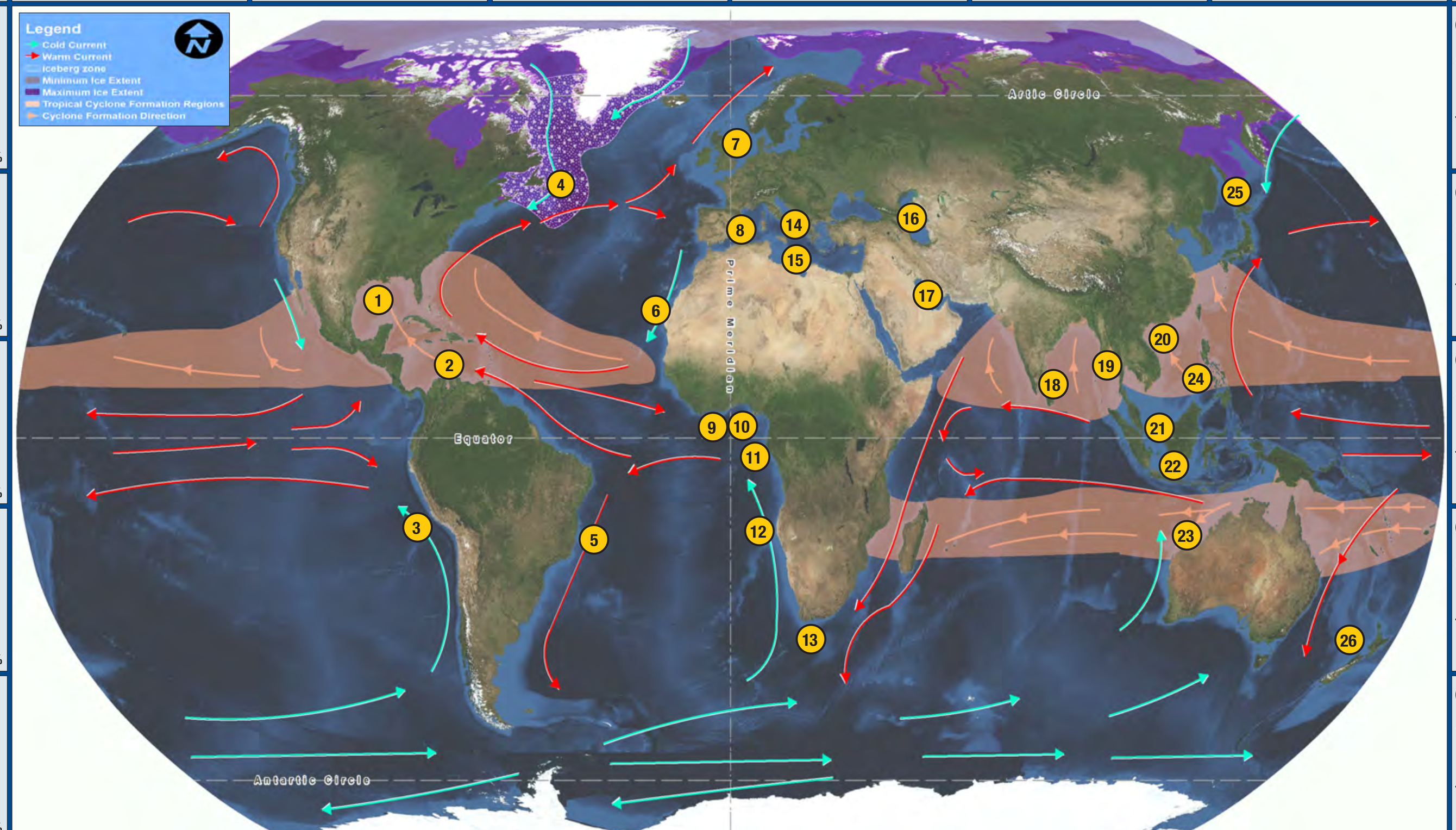
Class societies regulate the implementation of the guidelines set forth in the standards by giving specific steps to follow for class approval of a mooring system or installation.

1. **American Bureau of Shipping (ABS):** *www.eagle.org* then go to Resources > Rules & Guides > Downloads
2. **Bureau Veritas:** *www.veristar.com/wps/portal/bvrules*
3. **DNV GL:** *www.dnv.com/resources/rules_standards/index.asp*
4. **Lloyd's Register:** www.webstore.lr.org/category/1-marine.aspx

Courtesy of University of Houston, College of Technology, Petroleum Technology Initiative

WORLDWIDE OFFSHORE MOORING TRENDS (As of September 2013)

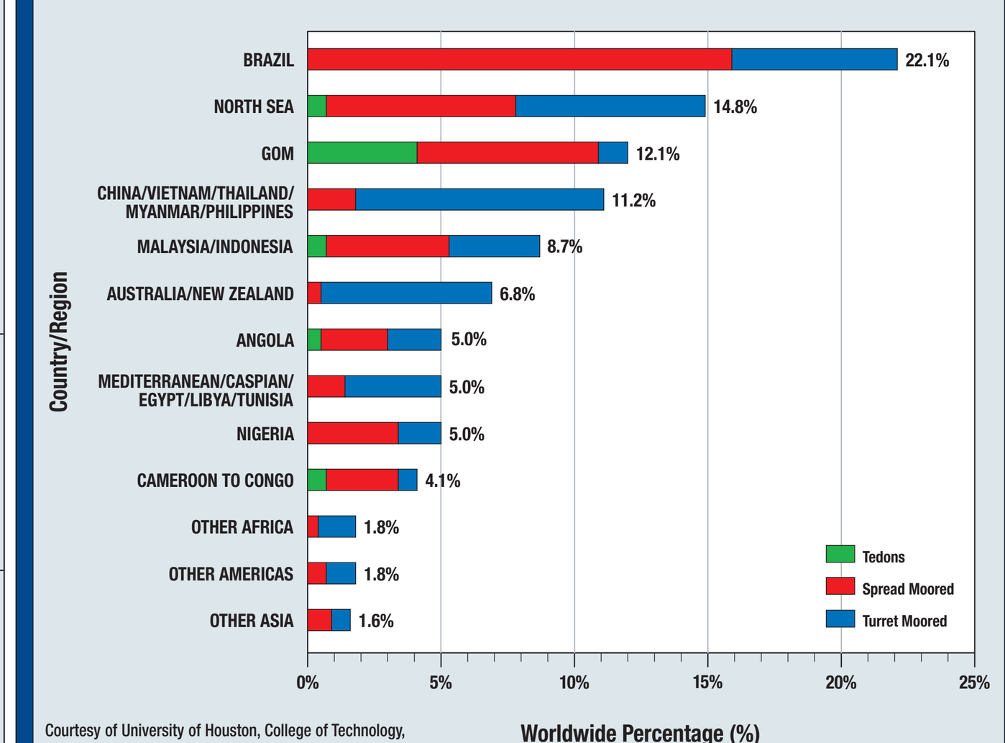
No.	Region	Spread Moored	Turret Moored	Tendon Moored
1	GOM	57%	9%	34%
2	Colombia/Venezuela	100%		
3	Peru	100%		
4	Canada/US Atlantic		100%	
5	Brazil	72%	28%	
6	Mauritania		100%	
7	North Sea	48%	48%	4%
8	Spanish Mediterranean	75%	25%	
9	Ghana/Ivory Coast	20%	80%	
10	Nigeria	68%	32%	
11	Cameroon to Congo	66%	17%	17%
12	Angola	50%	41%	9%
13	South Africa	50%	50%	
14	Adriatic/Italy		100%	
15	Egypt/Libya/Tunisia	17%	83%	
16	Caspian Sea		100%	
17	Qatar/Iran/UAE	50%	50%	
18	India	50%	50%	
19	Thailand/Myanmar		100%	
20	China/Vietnam	22%	78%	
21	Malaysia	40%	50%	10%
22	Indonesia	28%	66%	6%
23	Australia	7%	93%	
24	Philippines		100%	
25	Sakhalin	100%		
26	New Zealand		100%	



Data Source: UH Research, Mustang Engineering/*Offshore Magazine*, and Quest Offshore Databases for mooring system data and Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community for the world map data.

Prepared By: University of Houston, College of Technology, Petroleum Technology Initiative & Amy Hendrix, GIS Consultant

GRAPH 1: MOORING SYSTEM TRENDS BY REGION



Courtesy of University of Houston, College of Technology, Petroleum Technology Initiative

TABLE 3: THE APPLICATION OF MOORING SYSTEMS vs. OFFSHORE FACILITY TYPES

Courtesy of University of Houston, College of Technology, Petroleum Technology Initiative

LEGEND: G = Proven (green); Y = Not Proven (yellow)

Offshore Structure Types — Temporary: MODU (Semi-Submersible, Drill Ship (DP Rig)), Service Vessel, Floatel; Permanent/Production: TLP (Conventional & Mini-TLP), Semi (Production Semi), Spar (Truss Spar, Classic Spar, Cell Spar), Buoy (Loading/Prod. Buoy, Control Buoy), Non-Ship FPSO, Ship (FPSO, LNG Ship, FLNG Ship, Shuttle Tanker). Mooring Line Types: Chain, Wirerope, Polyester Fiber, Combined Line, Steel Pipe. Offshore Anchor Types: Pile (Suction Pile, Driven Pile), DEA, Plate Anchor.

Mooring Systems		D - Disconnectable P - Permanent	Semi-Submersible	Drill Ship (DP Rig)	Service Vessel	Floatel	Conventional & Mini-TLP	Production Semi	Truss Spar	Classic Spar	Cell Spar	Loading/Prod. Buoy	Control Buoy	Non-Ship FPSO	FPSO	LNG Ship	FLNG Ship	Shuttle Tanker	Chain	Wirerope	Polyester Fiber	Combined Line	Steel Pipe	Suction Pile	Driven Pile	DEA	Plate Anchor
Spread Mooring	Catenary	P	G	G	G	G		G	G	G	G	G	G	G	G		G		G	G	G	G		G	G	G	G
Spread Mooring	Taut	P	G	G	G	G		G	G	G	Y	G		G	G				G	G	G	G		G	G	G	G
Tendons & AP	Tension	P					G						G										G		G		
Single Point Mooring – Turret	Internal	D/P			G	G								G	G	G	G		G	G	G			G			G
Single Point Mooring – Turret	External	D/P												G	G		G		G	G	G			G	G	G	G
Single Point Mooring – CALM	Fixed Yoke	D												G	G	Y	Y	Y		G	G	G	G			G	G
Single Point Mooring – CALM	Soft Yoke	D												G	G	Y	Y	Y		G	G	G	G			G	G
Single Point Mooring – CALM	Hawser	D												G	G	Y	Y	G		G	G	G	G			G	G
Single Point Mooring – SALM	Tubular Riser & Yoke	D												Y	Y	G	G	G								G	G
Single Point Mooring – SALM	Chain Riser & Hawser	D												Y	Y	G	G	G	G	G						G	G

MOORING LINE COMPONENT TYPES: WIRE ROPE, POLYESTER FIBER ROPE, AND CHAIN

1. WIRE ROPE

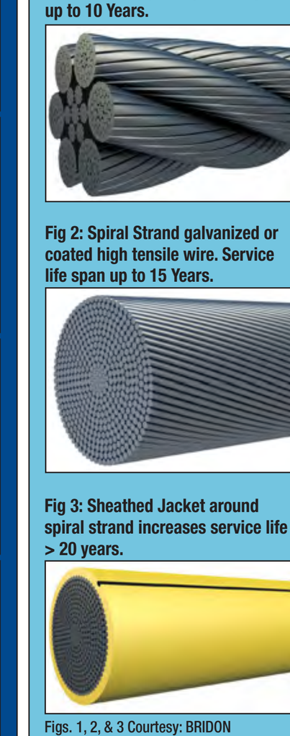


Fig. 1: Wire Rope for Deepwater MODU (Drilling Rigs) Mooring Lines Cross Section (6 x 34) – Life span up to 10 Years.

Fig 2: Spiral Strand galvanized or coated high tensile wire. Service life span up to 15 Years.

Fig 3: Sheathed Jacket around spiral strand increases service life > 20 years.

Figs. 1, 2, & 3 Courtesy: BRIDON

GRAPH 3: WIRE ROPE LIFE SPANS

WIRE ROPE TYPE	LIFE SPAN (Yrs.)
1. NON-GALVANIZ ED WIRE ROPE	Up to 10 Yrs.
2. GALVANIZED SPIRAL STRAND	Up to 15 Yrs.
3. SHEATHED SPIRAL STRAND	>20 Yrs.

2. FIBER ROPE (Typically Polyester)

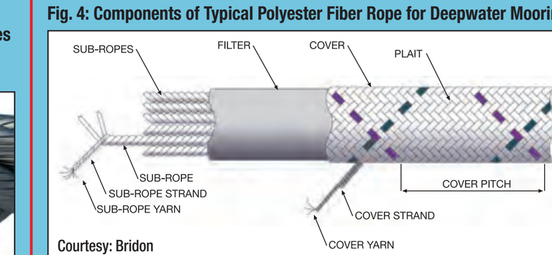


Fig. 4: Components of Typical Polyester Fiber Rope for Deepwater Mooring

Courtesy: Bridon

Fig. 6: Lankhorst's Fiber Rope with Torsional Reference Lines

Courtesy: Royal Lankhorst

Increasing Performance Life of Fiber Rope – The inclusion of a particle filter layer to limit the ingress of abrasive particles and marine finish on load bearing elements enhances the resistance to yarn on yarn abrasion ensures long term performance for field life in excess of 20 years.

Fig. 5 – Lankhorst's Polyester Fiber Rope on Deployment Reel Offshore

Courtesy: Royal Lankhorst

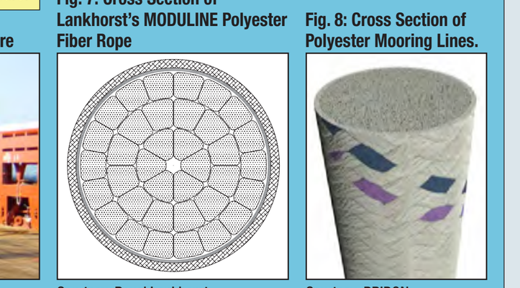


Fig. 7: Cross Section of Lankhorst's MODULINE Polyester Fiber Rope — Courtesy: Royal Lankhorst

Fig. 8: Cross Section of Polyester Mooring Lines. — Courtesy: BRIDON

3. MOORING CHAIN

Fig. 9: Studded Mooring Chain used at mud line & host facility. Chain actual field life performance is 15–20 years vs. typical design life of 20 to 25 years.

Courtesy: Delmar US

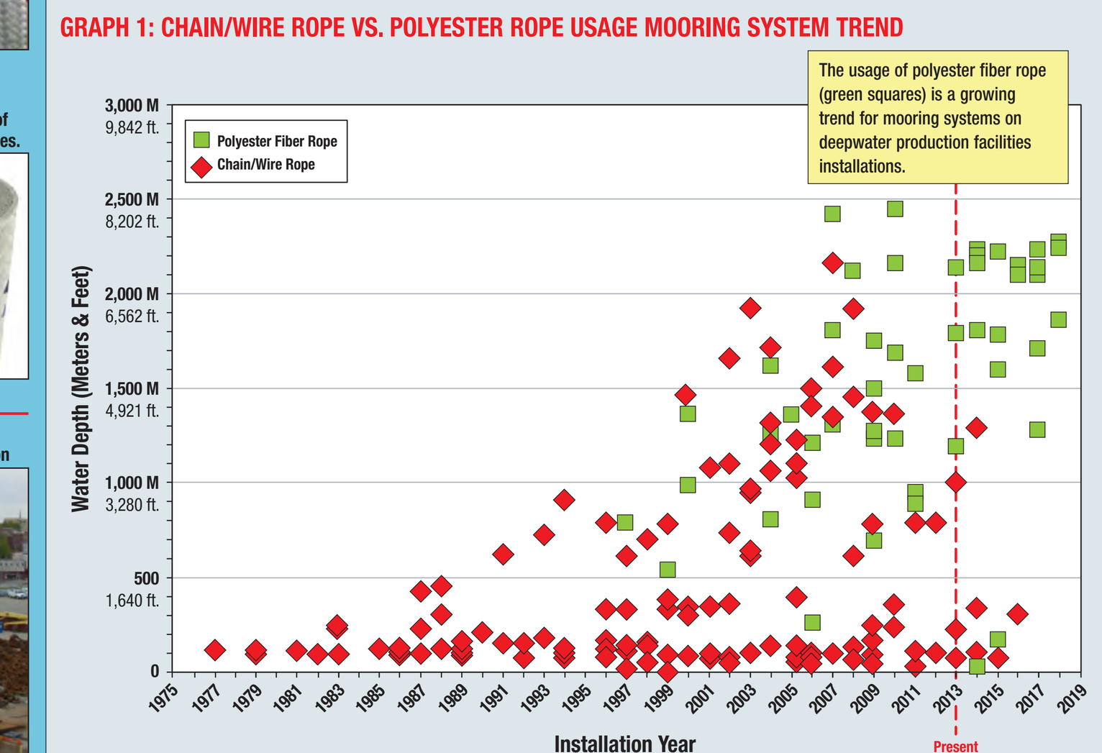
Fig. 10: Mooring Chain & Suction Piles Ready for Loadout & Installation

Courtesy: NOV APL

Advantages of Polyester for Mooring Lines

- Polyester rope gives a "softer" mooring system than steel wire rope; and therefore host motions are more compliant and riser friendly.
- Better Vortex Induced Motion (VIM) response to loop currents than Chain-Wire-Chain system.
- Affords smaller SCR departure angles.
- Allows the use of a significantly smaller turret buoy on FPSOs for enhanced safety and project viability.
- Up to 50% reduction in costs compared to conventional catenary mooring system.
- Approximately 80% reduction in wet weight of tension members (i.e. ropes) when converting from Wire to Polyester. The vertical mooring force on the platform is reduced by 50%. This reduction in wet weight and forces therefore increases usable payload.
- Up to 50% reduction in mooring pre-tension.
- Polyester rope does not corrode and there is no need for corrosion allowances on the diameter of the polyester like there is on chain and wire.

GRAPH 1: CHAIN/WIRE ROPE VS. POLYESTER ROPE USAGE MOORING SYSTEM TREND



Data Courtesy of Quest Offshore & Analysis by University of Houston, College of Technology, Petroleum Technology Initiative

MOORING LINE CONFIGURATIONS

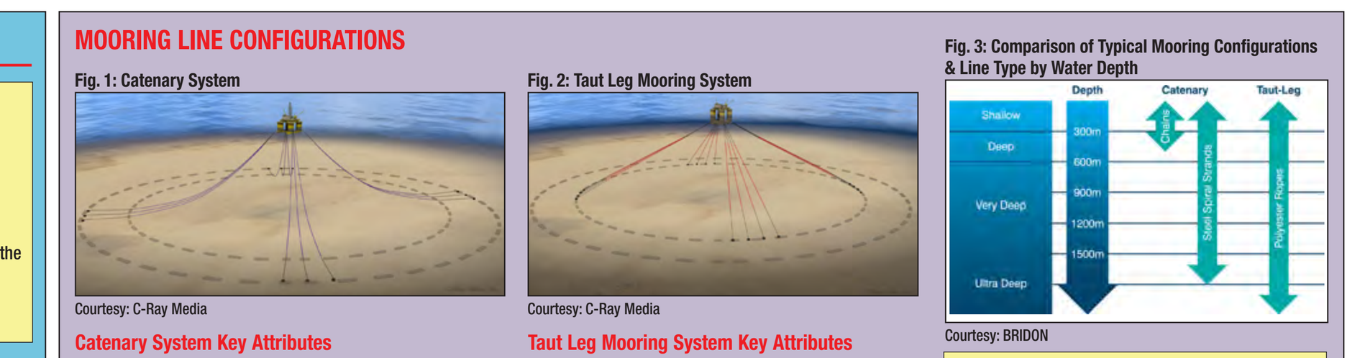


Fig. 1: Catenary System — Courtesy: C-Ray Media

Fig. 2: Taut Leg Mooring System — Courtesy: C-Ray Media

Fig. 3: Comparison of Typical Mooring Configurations & Line Type by Water Depth — Courtesy: BRIDON

Catenary System Key Attributes

- Used for chain/wire rope/chain mooring lines.
- Preferred mooring system type for deepwater MODUs for temporary mooring.
- Has a larger footprint compared to Taut System.

Taut Leg Mooring System Key Attributes

- Used for Polyester Mooring Lines with suction piles.
- Preferred mooring system type for long life deepwater production facilities.
- 40% reduction in footprint compared to Catenary Type.

Catenary and **Taut** describe the way the mooring line is suspended in the water column. Catenary systems have parabolic shape. Taut system mooring lines hang in a straight line between two points.

TYPES OF MOORING SYSTEMS

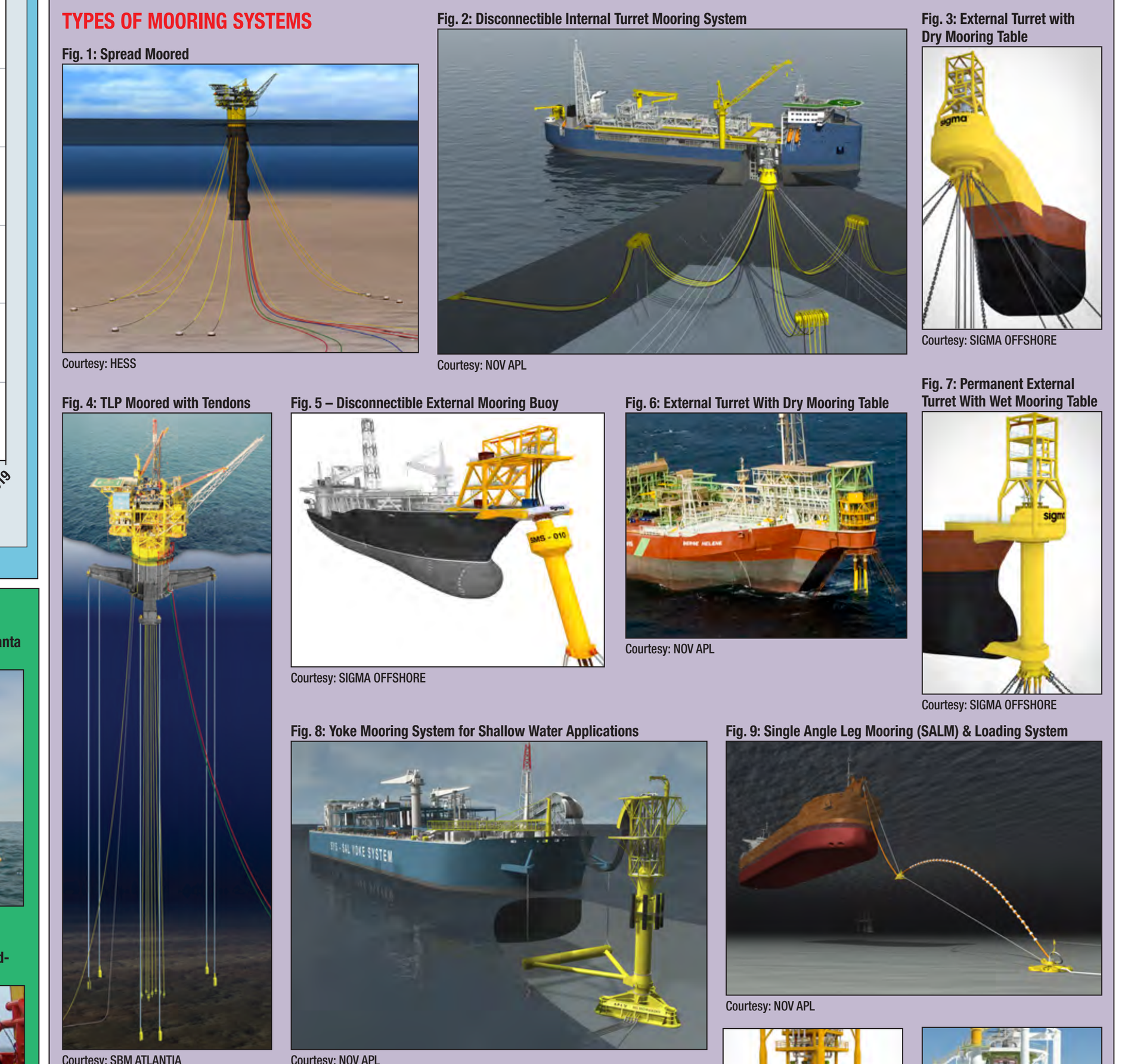


Fig. 1: Spread Moored — Courtesy: HESS

Fig. 2: Disconnectible Internal Turret Mooring System — Courtesy: NOV APL

Fig. 3: External Turret with Dry Mooring Table — Courtesy: SIGMA OFFSHORE

Fig. 4: TLP Moored with Tendons — Courtesy: SBM ATLANTIA

Fig. 5 – Disconnectible External Mooring Buoy — Courtesy: SIGMA OFFSHORE

Fig. 6: External Turret With Dry Mooring Table — Courtesy: NOV APL

Fig. 7: Permanent External Turret With Wet Mooring Table — Courtesy: SIGMA OFFSHORE

Fig. 8: Yoke Mooring System for Shallow Water Applications — Courtesy: NOV APL

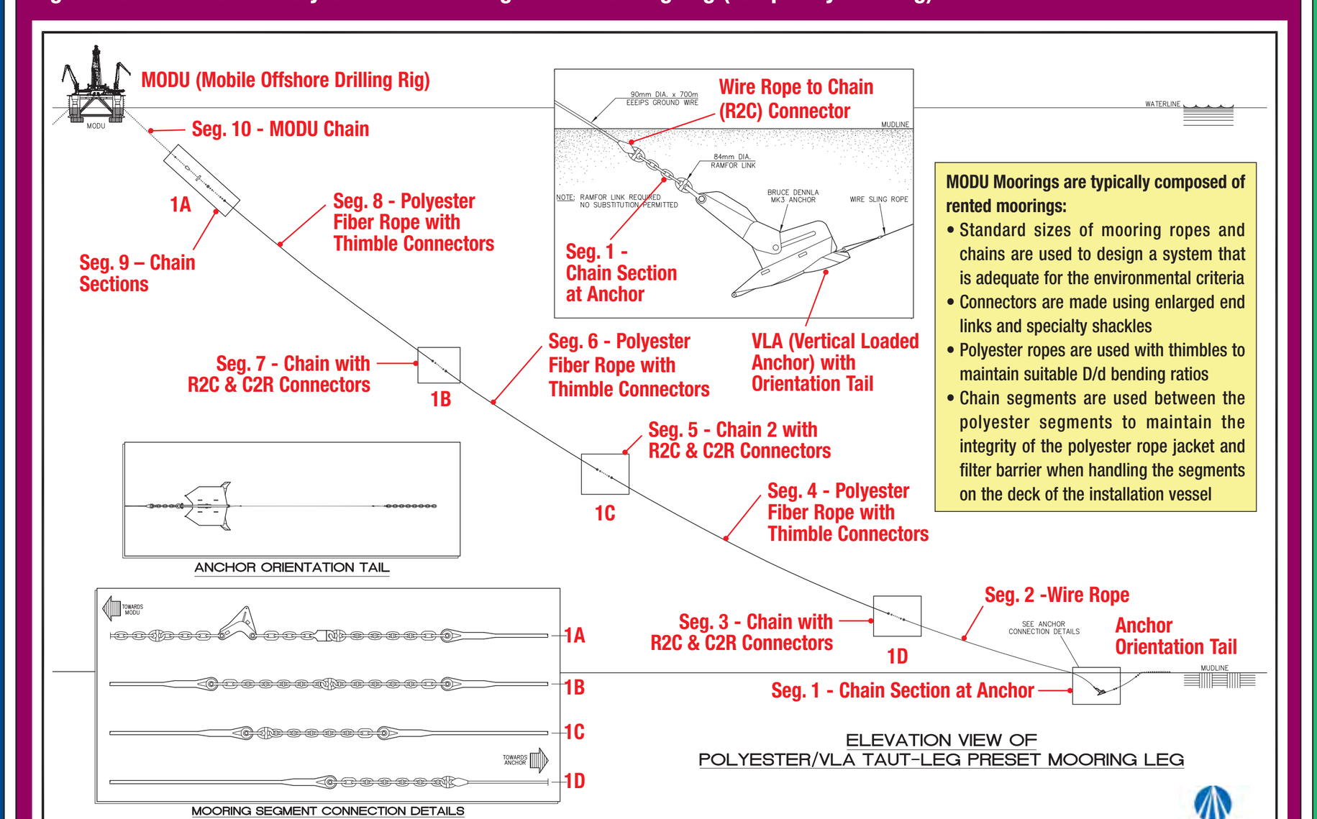
Fig. 9: Single Angle Leg Mooring (SALM) & Loading System — Courtesy: NOV APL

Fig. 10A & 10B: Non-Disconnectible Internal Turret Mooring System — Courtesy: SIGMA OFFSHORE; Courtesy: NOV

Fig. 11: CALM Buoy Mooring System — Courtesy: SOFEC

OFFSHORE MOORING LINES – SAMPLE ASSEMBLIES

Fig. 1: Elevation View of Polyester VLA Taut-Leg Preset Mooring Leg (Temporary Mooring)

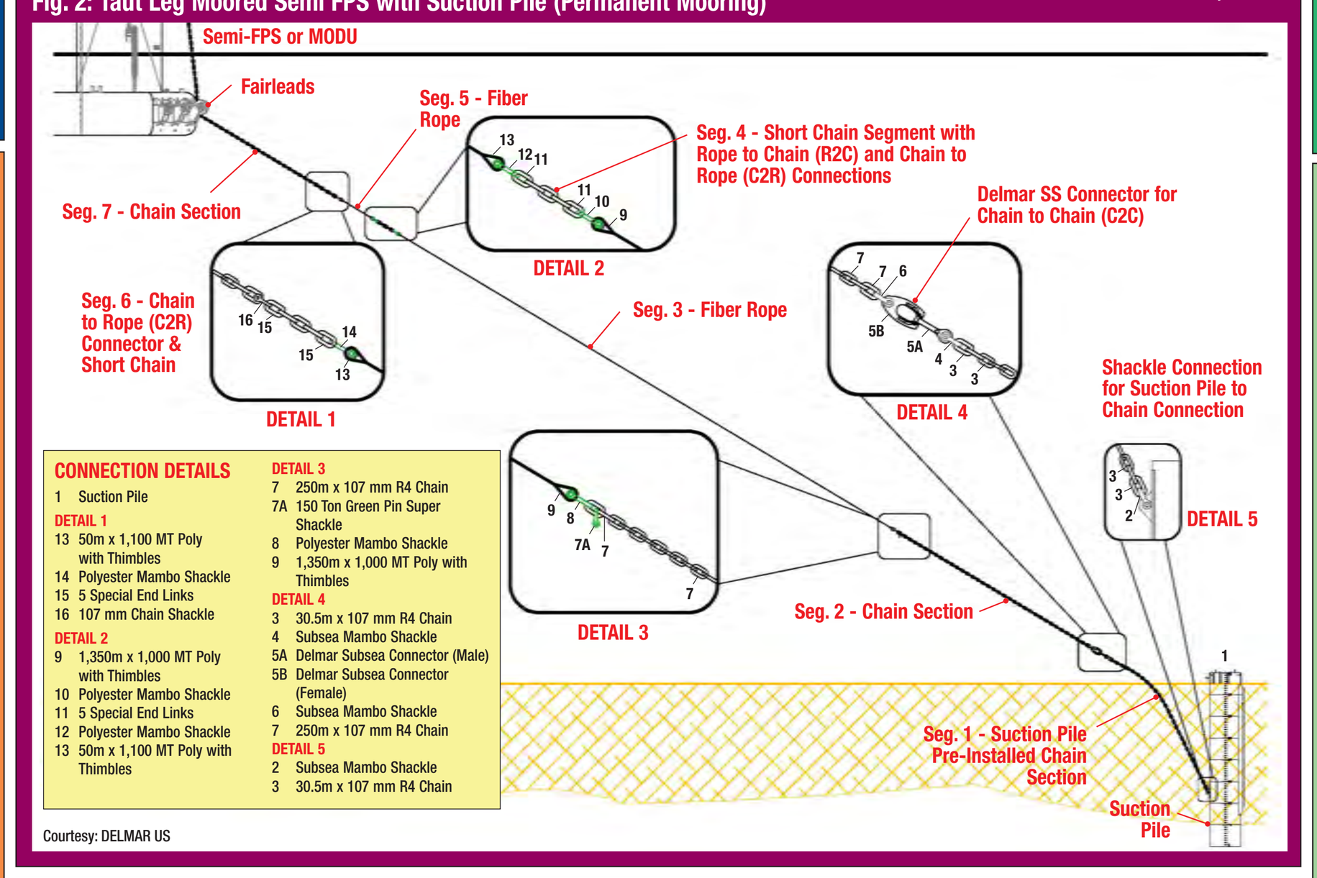


MODU Moorings are typically composed of rented moorings:

- Standard sizes of mooring ropes and chains are used to design a system that is adequate for the environmental criteria
- Connectors are made using enlarged end links and specialty shackles
- Polyester ropes are used with thimbles to maintain suitable D/d bending ratios
- Chain segments are used between the polyester segments to maintain the integrity of the polyester rope jacket and filter barrier when handling the segments on the deck of the installation vessel

Courtesy: InterMoor

Fig. 2: Taut Leg Moored Semi FPS with Suction Pile (Permanent Mooring)



CONNECTION DETAILS

1 Suction Pile

DETAIL 1
13 50m x 1,100 MT Poly with Thimbles
14 Polyester Mambo Shackle
15 5 Special End Links
16 107 mm Chain Shackle

DETAIL 2
9 1,350m x 1,000 MT Poly with Thimbles
10 Polyester Mambo Shackle
11 5 Special End Links
12 Polyester Mambo Shackle
13 50m x 1,100 MT Poly with Thimbles

DETAIL 3
7 250m x 107 mm R4 Chain
7A 150 Ton Green Pin Super Shackle
8 Polyester Mambo Shackle
9 1,350m x 1,000 MT Poly with Thimbles

DETAIL 4
3 30.5m x 107 mm R4 Chain
4 Subsea Mambo Shackle
5A Delmar Subsea Connector (Male)
5B Delmar Subsea Connector (Female)
6 Subsea Mambo Shackle
7 250m x 107 mm R4 Chain

DETAIL 5
2 Subsea Mambo Shackle
3 30.5m x 107 mm R4 Chain

Courtesy: DELMAR US

MOORING EQUIPMENT - WINCHES, FAIRLEADS AND CHAIN STOPPERS

Fig. 1: PUSNES Rotary Windlass — Courtesy: Aker Solutions Pusnes

Fig. 2: Chain Jacks: Pusnes Roller RamWinches on Perdido Spar — Courtesy: Aker Solutions Pusnes

Fig. 3: Chain Jacks Aker Solutions - Pusnes RamWinches™ on the Devil's Tower spar platform in the Gulf of Mexico at a depth of 1,720m. — Courtesy: Aker Solutions Pusnes

Fig. 4: Chain Jack on Kikeh Spar Hull — Courtesy: BARDEX

Fig. 5: Bardex Linear Chain Jack. Chain is Mechanically Held at All Times. Latches can not be released while under load. Used for SPAR, FPSO, and TLP Mooring and Tensioning Systems. — Courtesy: BARDEX

Fig. 6: BARDEX's Moveable Chain Jack on LLOG's Opti-EX Semi-FPS — Courtesy: BARDEX

Fig. 7: Pusnes Fairlead Chain Stoppers — Courtesy: Aker Solutions Pusnes

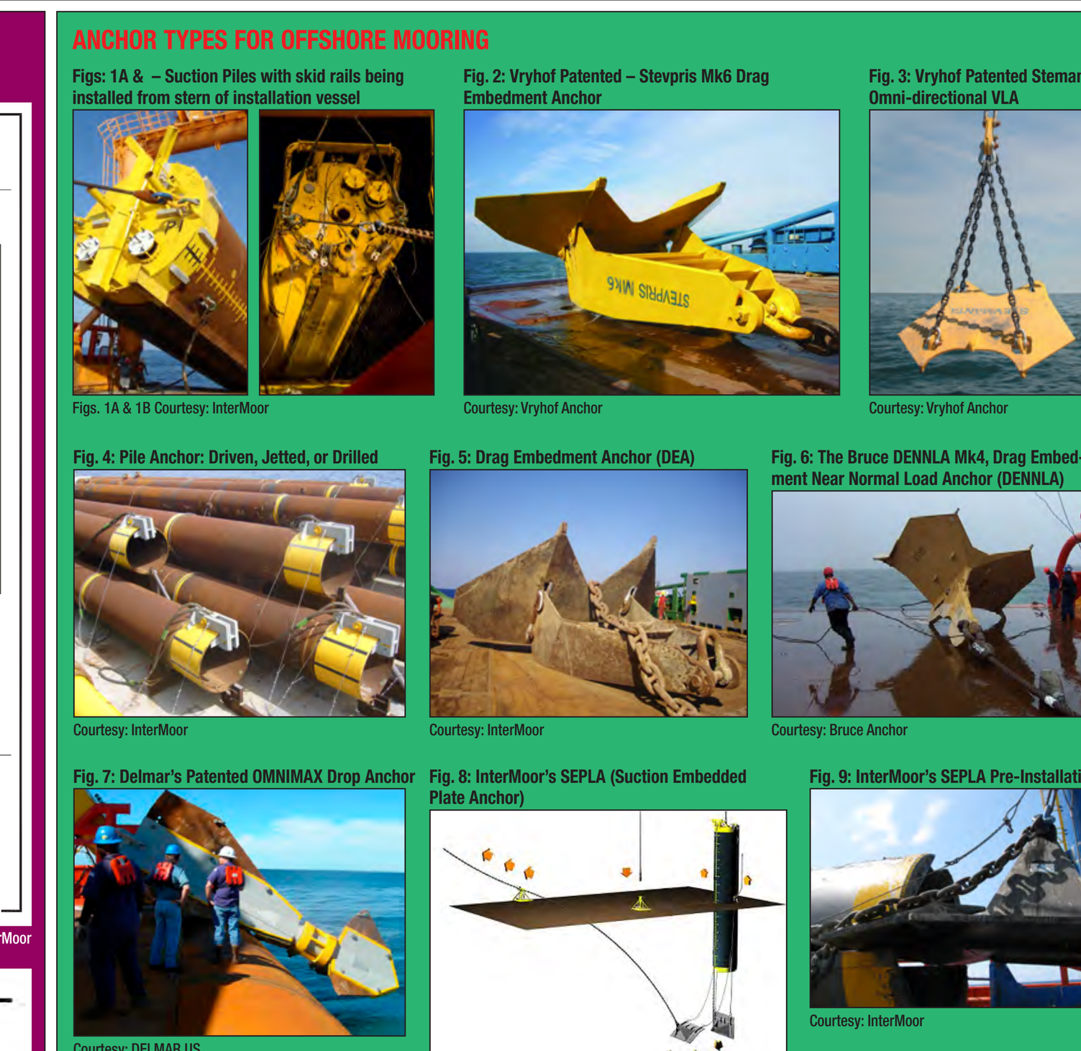
Fig. 8: Bardex's BarLatch Fairlead & Stopper — Courtesy: BARDEX

Fig. 9: Fairlead Above Waterline — Courtesy: NOV

Fig. 10: BARDEX's BarLatch Fairlead Stoppers On Total's CLOV FPSO Hull Fairlead & Stopper — Courtesy: BARDEX

Fig. 11: Fairleads On Semi MODU Hull ColumnFairlead & Stopper — Courtesy: Aker Solutions

ANCHOR TYPES FOR OFFSHORE MOORING



Figs: 1A & – Suction Piles with skid rails being installed from stern of installation vessel — Figs. 1A & 1B Courtesy: InterMoor

Fig. 2: Vryhof Patented – Stevpris Mk6 Drag Embedment Anchor — Courtesy: Vryhof Anchor

Fig. 3: Vryhof Patented Stemanta Omni-directional VLA — Courtesy: Vryhof Anchor

Fig. 4: Pile Anchor: Driven, Jetted, or Drilled — Courtesy: InterMoor

Fig. 5: Drag Embedment Anchor (DEA) — Courtesy: InterMoor

Fig. 6: The Bruce DENNLA Mk4, Drag Embedment Near Normal Load Anchor (DENNLA) — Courtesy: Bruce Anchor

Fig. 7: Delmar's Patented OMNIMAX Drop Anchor — Courtesy: DELMAR US

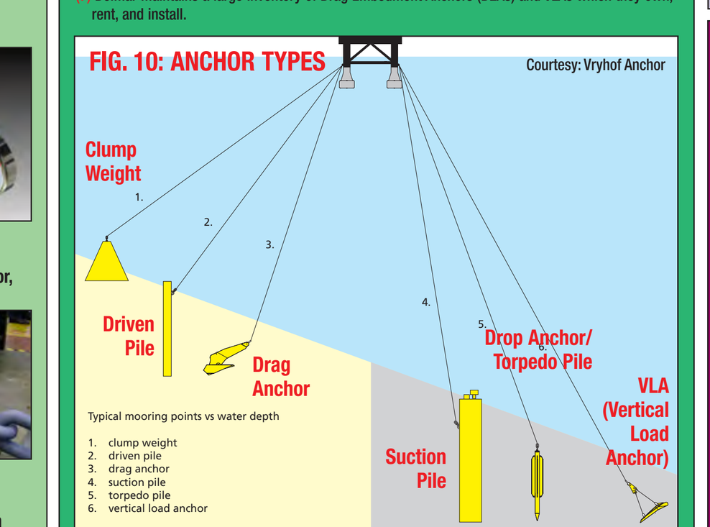
Fig. 8: InterMoor's SEPLA (Suction Embedded Plate Anchor) — Courtesy: InterMoor

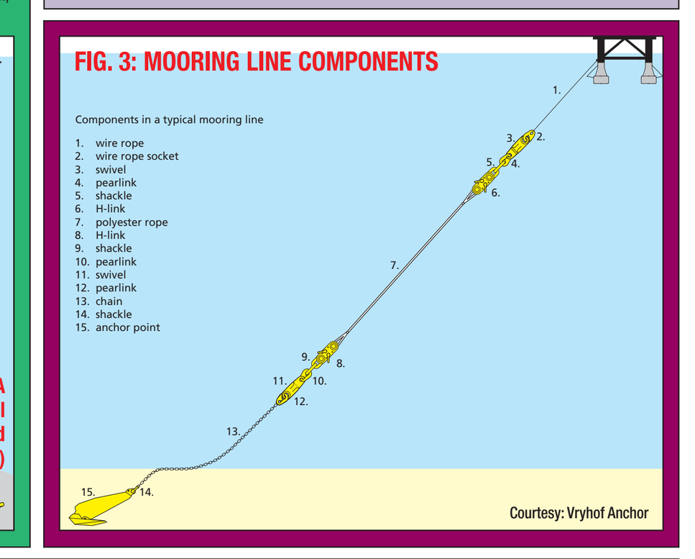
Fig. 9: InterMoor's SEPLA Pre-Installation — Courtesy: InterMoor

TABLE 4: ANCHOR MANUFACTURERS BY TYPE

Manufacturers / Company Name	Pile: Suction Pile	Pile: Driven Pile	Drop Anchor: Torpedo Pile	Drop Anchor: Omni Max ™	DEA: DEA	DEA: VLA	Plate: SEPLA (2)	Plate: Bruce MK4 & MK5	Plate: Stevpris (6)
BRUCE ANCHORS					●	●		●	
DELMAR	●			● (5)	(7)	(7)			
FLUKE ENGENHARIA (1)			●						
InterMoor	●	●	● (4)		(3)	(3)	●		
VRYHOF ANCHORS	●				●	●			●

(1) Contracted by Petrobras to fabricate the Torpedo Piles.
(2) SEPLA is proprietary to InterMoor and is solely manufactured and installed by InterMoor.
(3) InterMoor does not manufacture DEAs or VLAs. However, they own, rent, and install these anchor types.
(4) InterMoor is licensed by Petrobras to fabricate and install Torpedo Piles in GOM.
(5) OMNIMAX is the trade mark of Delmar.
(6) Also includes Stevmanta, and Stevshark anchors.
(7) Delmar maintains a large inventory of Drag Embedment Anchors (DEAs) and VLAs which they own, rent, and install.





OFFSHORE MOORING CONNECTORS: Connecting Mooring System Components Together

Fig. 1: "H-Link" Connector: Anchor to Polyester Rope — Courtesy: InterMoor

Fig. 2: "H-Link" Connector: Rope to Rope (R2R)

Fig. 3: "Y-Link" Connector: Rope to Rope (R2R)

Fig. 4: "Pear Link" Connector: Rope to Chain (R2C)

Figs. 2, 3, and 4 Courtesy: Lankhorst Ropes

Fig. 5: Inter-M Swivel Connector for Chain to Chain (C2C) 360° Rotation — Courtesy: InterMoor

Fig. 6: LankoFirst Rope to Rope (R2R) Clam Connector for Permanent Mooring and MODU Applications

Fig. 7– LankoFirst Rope to Chain (R2C) Connector, An Alternative to "H" Link

Figs. 6 & 7 Courtesy: Royal Lankhorst

Figs. 8: Ballgrab Female Connector Used on a Disconnectable Buoy for FPSO Turret — Courtesy: First Subsea

Fig. 9: Flintstone Technology's FTL Subsea Mooring Connector — Courtesy: Flintstone Technology

Fig. 10: LankoFirst's Snap Connector for Fiber Rope to Fiber Rope (R2R) — Courtesy: First Subsea

Fig. 11: LankoFirst's Clam Connector (Opened) — Courtesy: First Subsea

Fig. 12: Open Socket (Female End) Link for Wire Rope — Courtesy: LeBeon Manufacturing

Fig. 13: Closed Socket (Male End) with Shackle, Wire Rope to Chain (R2C) — Courtesy: LeBeon Manufacturing

Fig. 18: H Link With Padeye Chain to Chain (C2C) — Courtesy: LeBeon Manufacturing

Fig. 14: Closed Socket (Male End) Link for Wire Rope End, Technology Indicated in Red — Courtesy: LeBeon Manufacturing

Fig. 15: Ballgrab Stab-In On Buoy — Courtesy: First Subsea

Fig. 16: Sister Connector – Fiber Rope Thimble to Fiber Rope Thimble (R2R) — Courtesy: LeBeon Manufacturing

Fig. 17: Open Socket &Y-Link Connectors, Wire Rope to Chain (R2C) — Courtesy: LeBeon Manufacturing

Fig. 19: First Subsea's Ballgrab SMC Male Connector with Mooring Chain — Courtesy: First Subsea

Fig. 20: Y-Link Connection Open Wire Rope Socket to Chain (R2C) Connection — Courtesy: LeBeon Manufacturing

Fig. 21: Thimble & Shackle for Fiber Rope to Chain (R2C) Connection — Courtesy: LeBeon Manufacturing

Fig. 22: ROV Operable H-Link — Courtesy: LeBeon Manufacturing

Fig. 23: Ballgrab Connector Series II, ball and taper, Subsea Mooring Connector (SMC) – Female Connector in Docking Porch Ontop of a Suction Pile. — Courtesy: First Subsea

Fig. 24 – Delmar's Subsea Mooring Connector for Chain, Wire Rope, and Polyester Rope Combinations — Courtesy: Delmar US

Fig. 25 – Balltec's MoorLOK Connector On top of Suction Pile (C2C)

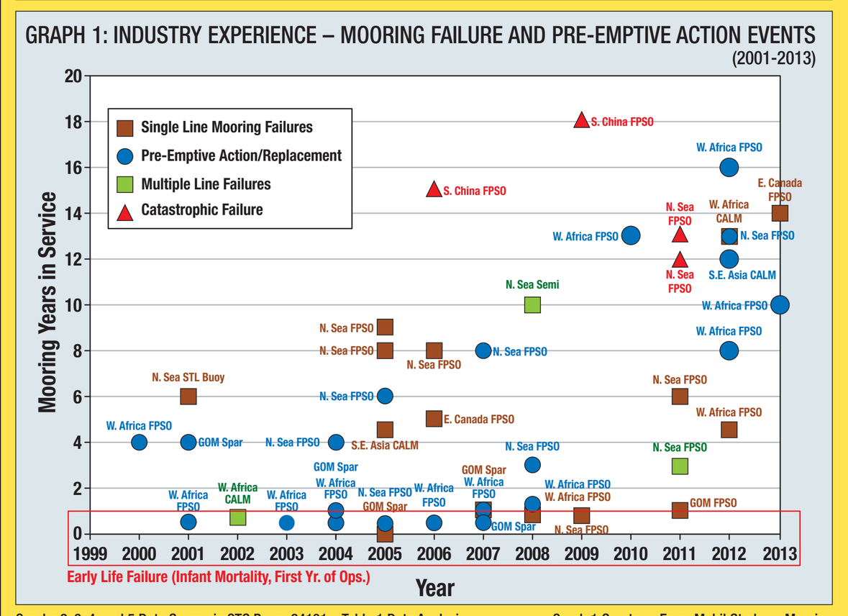
Fig. 26 – Balltec's MoorLOK Male Connector (C2C) with "Y" Link

Figs. 25 & 26 Courtesy: Balltec

MOORING SYSTEMS – INTEGRITY ISSUES ON FPSs

Trend: The purpose of this Section is to make the industry aware of integrity issues & trends with regards to Mooring Systems for FPSs. According to *OTC Paper 24181* the analysis "indicates a trend in which the intended design performance of moorings does not meet operational performance"

GRAPH 1: INDUSTRY EXPERIENCE – MOORING FAILURE AND PRE-EMPTIVE ACTION EVENTS (2001-2013)

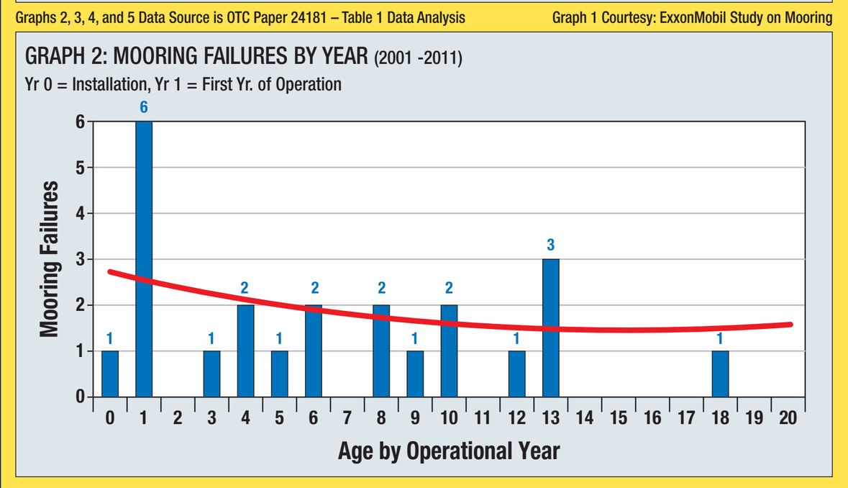


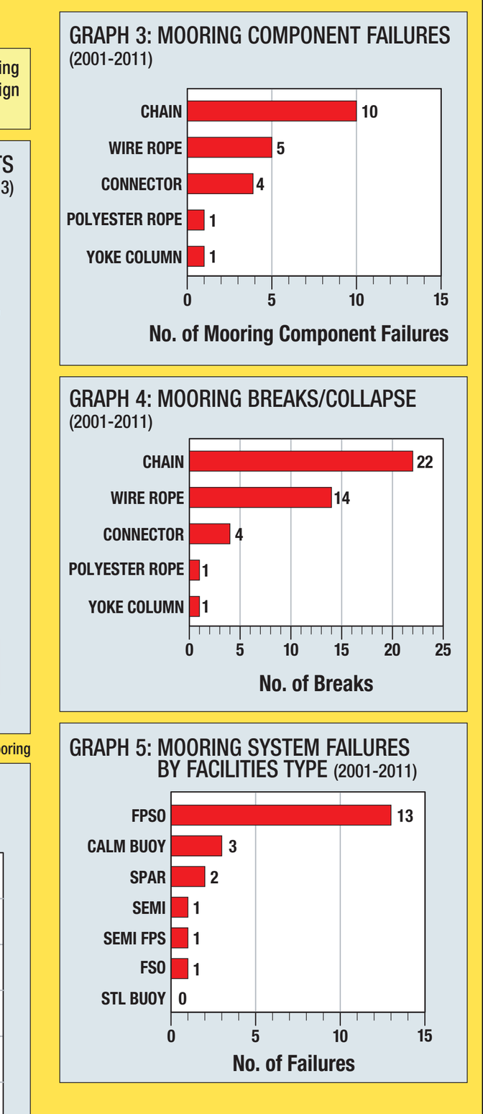
Graphs 2, 3, 4, and 5 Data Source is OTC Paper 24181 – Table 1 Data Analysis

Graph 1 Courtesy: ExxonMobil Study on Mooring

GRAPH 2: MOORING FAILURES BY YEAR (2001 -2011)

Yr 0 = Installation, Yr 1 = First Yr. of Operation





Additional Ref. Material: *Mooring Integrity Guidance, Nov. 2008*; Published by The United Kingdom Offshore Oil and Gas Industry Association Limited (Oil & Gas UK).

OFFSHORE MOORING PATTERNS (FOR TEMPORARY & PERMANENT MOORING)

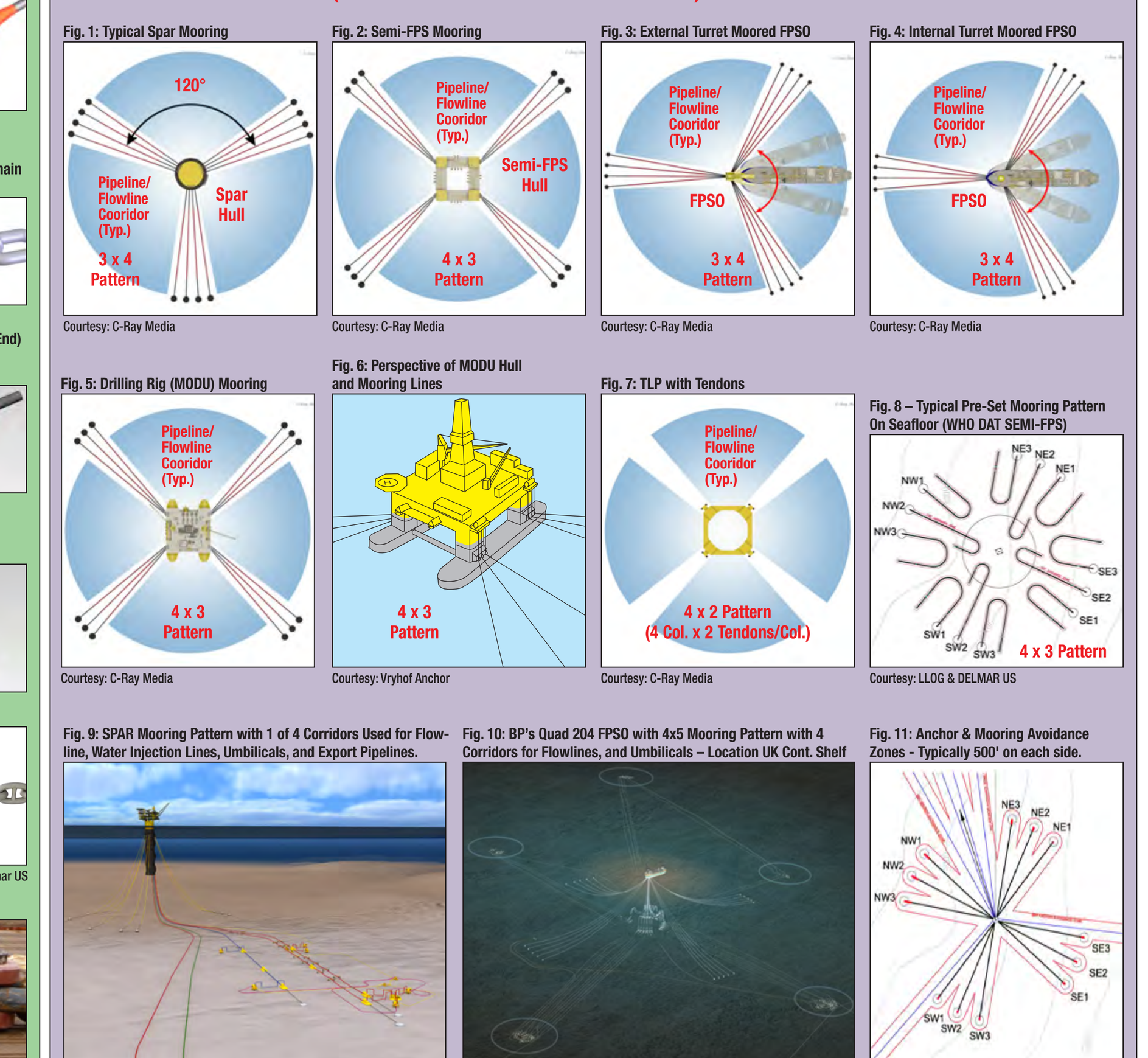


Fig. 1: Typical Spar Mooring — Courtesy: C-Ray Media

Fig. 2: Semi-FPS Mooring — Courtesy: C-Ray Media

Fig. 3: External Turret Moored FPSO — Courtesy: C-Ray Media

Fig. 4: Internal Turret Moored FPSO — Courtesy: C-Ray Media

Fig. 5: Drilling Rig (MODU) Mooring — Courtesy: C-Ray Media

Fig. 6: Perspective of MODU Hull and Mooring Lines — Courtesy: Vryhof Anchor

Fig. 7: TLP with Tendons — Courtesy: C-Ray Media

Fig. 8 – Typical Pre-Set Mooring Pattern On Seafloor (WHO DAT SEMI-FPS) — Courtesy: LLOG & DELMAR US

Fig. 9: SPAR Mooring Pattern with 1 of 4 Corridors Used for Flowline, Water Injection Lines, Umbilicals, and Export Pipelines. — Courtesy: HESS; Graphics By: C-Ray Media

Fig. 10: BP's Quad 204 FPSO with 4x5 Mooring Pattern with 4 Corridors for Flowlines, and Umbilicals – Location UK Cont. Shelf — Courtesy: BP

Fig. 11: Anchor & Mooring Avoidance Zones - Typically 500' on each side. — Courtesy: LLOG & DELMAR US

CHART 1: OFFSHORE MOORING SUPPLIER MATRIX (AS OF SEPT., 2013)

OFFSHORE OIL & GAS MOORING SYSTEM & SERVICE COMPONENT PROVIDERS

MOORING SYSTEM ENGINEERING: AKER SOLUTIONS akersolutions.com; AMOG CONSULTING Amogconsulting.com; BOSKALIS OFFSHORE boskalis.com/offshore; BPP-TECH bpp-tech.com; CORTLAND COMPANY cortlandcompany.com; DEEPSEA GROUP LTD. Deepseaeng.com; DELMAR SYSTEMS delmarus.com; FLOATEC Floatec.com; HOUSTON OFFSHORE ENGINEERING Houston-offshore.com; InterMoor InterMoor.com; KBR (GRANHERNE SUBSIDIARY) KBR.com; LOC NORGE AS LOC-GROUP.COM; LONDON MARINE CONSULTANTS LONDONMARINE.CO.UK; MCS KENNY mcskenny.com; MOORING SYSTEM SOLUTIONS PTY LTD. (MOORSURE) Moorsure.com.au; OFFSPRING INTERNATIONAL (OIL) offspringinternational.com

MOORING CLASSIFICATION & CERTIFICATION: ABS eagle.org; API API.ORG; BUREAU VERITAS Veritas.com; DNV DNV.ORG; LLOYD'S REGISTER LR.ORG; SBM OFFSHORE sbmoffshore.com; SIGMA OFFSHORE SIGMAOFFSHORE.COM; SOFEC sofec.com; TECHNIP technip.com; VIKING SEA TECH AS vikingseatech.com; VRYHOF ENGINEERING Ltd. Vryhof.com; WORLEYPARSONS Worleyparsons.com

MOORING LINE COMPONENTS

- **FIBER ROPES:** BEXCO BV http://www.bexco.be/; BRIDON bridon.com; CORTLAND COMPANY cortlandcompany.com; CSL ROPES cslropes.com.br; DSR CORP dsrcorp.com; InterMoor InterMoor.com; LANKHORST EURO NETE lankhorsteuronete.com; OTS otsas.no; PARKER SCANROPE AS scanrope.no; SAMSON samsonrope.com; TEUFELBERGER teufelberger.com/en; TRION Co., Ltd trioncorp.co.kr; UNIROPE unirope.com; WHITEHILL MANUFACTURING whitehillmfg.com
- **STEEL WIRES:** ALLOY WIRE INTERNATIONAL alloywire.com; ARCELOMITTAL Arcelormittal.com/wiresolutions; BRIDON INTERNATIONAL LTD bridonltd.com; BROOKFIELDWIRE brookfieldwire.com; DCL MOORING & RIGGING dcl-usa.com; InterMoor InterMoor.com; KISWIRE LTD kiswire.com; MOORLINK moorlink.com; PARKER HANNIFIN CORPORATION parker.com; REDAELLI TECNA S.P.A. redaelli.com; SCANROPE scanropemarine.com; TOKYO WIRE ROPE tokyorope.co.jp; USHA MARTIN ushamartin.com; WASHINGTON CHAIN & SUPPLY wachain.com
- **CHAINS:** COLUMBUS MCKINNON CORPORATION cmworks.com; COORDINATED COMPANIES ceccwrr.com; DAI HAN ANCHOR CHAIN MFG. CO., LTD. dhac.co.kr; DCL MOORING & RIGGING dcl-usa.com; DSR CORP dsrcorp.com; HAMANAKA CHAIN MFG. CO. LTD. hamanaka-chain.co.jp; InterMoor InterMoor.com; JIANGSU ASIAN STAR ANCHOR CHAIN CO. LTD anchor-chain.com; KETTENFABRIK MESTER GMBH mesterkette.com; LAIWU STEEL ZIBO ANCHOR CHAIN CO., LTD. lgchains.com; MARIT marit.fr; RAMNAS BRUK AB ramnas.com; SANMAR CHAIN INTERNATIONAL PTE LTD. sci-chain.com; SOTRA ANCHOR & CHAIN Sotra.net; UNIROPE unirope.com; VICINAY MARINE Vicinaymarine.com; WASHINGTON CHAIN & SUPPLY wachain.com; ZHENGMAO GROUP CO. LTD. Zszhongnan.com

ANCHORS & SUCTION PILES: BLADT INDUSTRIES AS bladt.dk; BRUCE ANCHOR bruceanchor.co.uk; CANYON OFFSHORE helixesg.com; CORTLAND COMPANY cortlandcompany.com; DCL MOORING & RIGGING dcl-usa.com; DELMAR SYSTEMS delmarus.com; InterMoor intermoor.com; MENCK menck.com; SOTRA ANCHOR & CHAIN SOTRA.NET; SPT OFFSHORE sptoffshore.com; VIKING SEA TECH AS vikingseatech.com; VRYHOF ANCHORS B.V. vryhof.com

ACCESSORIES

- **WINCHES:** Aker Pusnes AS akersolutions.com; AMCLYDE rokrem.com; APPLETON MARINE, INC. Appletonmarine.com; BODEWES bodewes.com; BROHL Broehl.de; OIL STATES SKAGIT SMATCO Oilstates.com; NOV nov.com; RAPP MARINE Rappmarine.com; ROLLSROYCE Rolls-royce.com; TIMBERLAND EQUIPMENT Timberland-group.com
- **FAIRLEADS, CHAIN STOPPERS, CHAIN JACKS:** AKER SOLUTIONS akersolutions.com; BARDEX Corporation bardex.com; BROHL Broehl.de; NOV nov.com; ROLLSROYCE Rolls-royce.com; SMITHBERGER smithberger.com; TIMBERLAND EQUIPMENT Timberland-group.com; TRELLEBORG MARINE SYSTEMS Trelleborg.com/marine
- **CONNECTORS, SHACKLES, CHASERS:** BALLTEC Balltec.com; BRUCE ANCHOR bruceanchor.co.uk; DELMAR SYSTEMS delmarus.com; FEUERSTEIN GMBH feubo.com; FIRST SUBSEA firstsubsea.com; FLINTSTONE TECHNOLOGY flint-tech.com/subsea.html; FRANKLIN OFFSHORE INTERNATIONAL franklin.com.sg; GREENPIN greenpin.com; GROFSMEDERIJ NIEUWKOOP B.V. gnweb.com; GUNNEBO JOHNSON CORP gunnebojohnson.com; InterMoor intermoor.com; LeBeon Manufacturing le-beon.com; LHR MARINE/FEURSTEIN lhrmarine.com; KOHLSWA GJUTERI AB kohlswagjuteri.se; MILLER LIFTING millerproducts.net
- **MOORING BUOYS/ BUOYANCY:** BALMORAL balmoral-offshore.com; CRP crpgroup.com; DCL MOORING & RIGGING dcl-usa.com; DELMAR SYSTEMS delmarus.com; InterMoor intermoor.com; MOORLINK moorlink.com; OIL STATES Oilstates.com; OCEANSIDE EQUIPMENT LTD.; SMITH BERGER MARINE smithberger.com; THE CROSBY GROUP thecrosbygroup.com; VICINAY MARINE Vicinaymarine.com

MOORING MONITORING/ INSTRUMENTATION: ASTRO TECHNOLOGY astrotechnology.com; BMT SCIENTIFIC MARINE SERVICES Scimar.com; FUGRO GEOS Geos.com/offshore-systems/; INTERMOOR/PULSE STRUCTURAL MONITORING InterMoor.com; MEASUREMENT TECHNOLOGY NW mtnw-usa.com.com; NESSCO Nessco.rig.net; STRAINSTALL Strainstall.no; TRELLEBORG MARINE SYSTEMS Trelleborg.com/marine; WELAPTEGA MARINE welaptega.com; WFS SUBSEA wfs-tech.com; 2HOFFSHORE 2hoffshore.com

TURRET DESIGNERS/ SUPPLIERS: BLUEWATER bluewater.com; LONDON MARINE CONSULTANTS londonmarine.co.uk; NOV (FORMERLY APL) nov.com/Production/Floating_Production_Solutions.aspx; ORWELL OFFSHORE orwelloffshore.com; SBM sbmoffshore.com; SIGMA OFFSHORE Sigmaoffshore.com; SOFEC sofec.com

MOORING SYSTEM INSTALLERS/PM: BOSKALIS OFFSHORE boskalis.com/offshore; DELMAR SYSTEMS delmarus.com; EMAS AMC emas.com; HEEREMA MARINE CONTRACTORS (HMC) hmc.heerema.com; InterMoor intermoor.com; JUMBO OFFSHORE Jumbo-offshore.nl; MCDERMOTT INTERNATIONAL, INC. mcdermott.com; OFFSHORE INSTALLATION SERVICES LTD. (OIS) ois-ltd.com; SBM OFFSHORE sbmoffshore.com; SOUTHGATE MARINE & OFFSHORE SERVICES LTD. Southgatemarine.com; SUBSEA 7 le-beon.com; TECHNIP technip.com; VIKING SEA TECH AS vikingseatech.com

LIST OF APPROVED MANUFACTURES – For Mooring Chain, Anchors, Wire Rope

1. **AMERICAN BUREAU OF SHIPPING: APPROVED MANUFACTURERS SHIP ANCHOR AND OFFSHORE MOORING CHAIN** (Updated weekly by ABS) *http://www.eagle.org/eagleExternalPortalWEB/ShowProperty/BEA%20Repository/AppProdsMFG/ApprovedListings/27CChain*
2. **Lloyd's Register Group Limited (LR): List 9a list of Approved Manufacturers of Chain Cable for Ships and Offshore Mooring** *https://www.cdlive.lr.org/information/Documents/Approvals/ApprovedManufactures/list9a.pdf*
3. **Lloyd's Register Group Limited (LR): List 9b Approved Manufacturers of Fittings for Chain Cable** *https://www.cdlive.lr.org/information/Documents/Approvals/ApprovedManufactures/list9b.pdf*
4. **Lloyd's Register Group Limited (LR): List 11 Approved Manufacturers of Steel Wire Rope** *https://www.cdlive.lr.org/information/Documents/Approvals/ApprovedManufactures/list11.pdf*

Note 1: The companies shown on this supplier matrix represent those companies that are service providers, component providers or manufacturers of the components.

Prepared By University of Houston, College of Technology, Petroleum Technology Initiative