LANKHORST

# STRENGTH IN DEPTH

OG OIL & GAS

# DEEPWATER MOORING.

WIRECO
A World Ahead

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# LANKHORST OFFSHORE... STRENGTH IN DEPTH

Lankhorst Offshore is a world leader in the development, engineering and manufacture of synthetic fibre ropes for deepwater mooring, fibre rope deployment systems, riser and mid-water arch tether systems, single point mooring offloading systems and floating offshore wind turbines.

Innovation is at the heart of our business. We are committed to setting the standard for performance and reliability in the most demanding offshore environments. Our strengths in engineering and technical know-how are matched by an in-depth knowledge of offshore applications stretching back over more than 200 years.

Lankhorst Offshore continuously strives for improved product performance, customer satisfaction and product innovation. As part of WireCo® WorldGroup, the world's leader in manufacturing, engineering, and distributing wire rope, synthetic rope, specialized assemblies, wire products and electromechanical cable, we draw on extensive research and testing facilities at WireCo® WorldGroup's Global Synthetics R&D facility in Portugal. Here we have an on-going research program into mooring and deployment rope materials and constructions, designed to support offshore energy companies in meeting ever more demanding project and environmental challenges.

We have fully equipped production sites and R&D departments, located in Portugal and at our sister company Lankhorst Euronete Brasil Indústria e Comércio Ltds (LEB), with capabilities to produce a wide range of offshore ropes.

Lankhorst Euronete Portugal has been certified by Lloyd's Register Quality Assurance and Lankhorst Euronete Portugal by Bureau Veritas Certification according to ISO 9001:2015.

Lankhorst Offshore trades under the names of Lankhorst Euronete Portugal S.A. (LEP) and Lankhorst Euronete Brasil (LEB).

Certificate of Approval

Lankhorst-Euronete Portugal S.A.

LANKHORST EURONETE BRASIL INDÚSTRIA E COMÉRCIO LTDA.

Rua Minas Gerais, 1920, Distrito Industrial, 26373-280 - **Queimado/RJ**

**Brazil**

*Bureau Veritas Certification Holding SAS – UK Branch certifies that the Management System of the above organization has been audited and found to be in accordance with the requirements of the Management System standards detailed below.*

*Standards*

**ISO 9001:2015**

*Scope of Certification*

**DESIGN, DEVELOPMENT, MANUFACTURE AND COMMERCIALIZATION OF SYNTHETIC FIBER ROPES, SUCH AS: TWISTED ROPES, BRAIDED ROPES, MOORING ROPES AND ROPES FOR ANCHORING SYSTEMS.**

Original cycle start date: **08 February 2012**

Expiry date of previous cycle: **06 February 2018**

Certification / Recertification Audit date: **14 December 2017**

Certification / Recertification cycle start date: **06 February 2018**

Subject to the continued satisfactory operation of the organization's Management System, this certificate expires on: **05 February 2021**

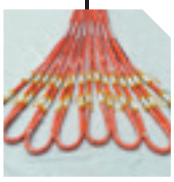
Certificate N°: **BR027701** Version: **1** Revision date: **08 January 2018**

OG **OIL & GAS**

CR Cranes & OEM | MI Mining | EP Engineered products | WI Wire | MA Maritime | YA Yarns | FI Fishing


DEEPWATER MOORING

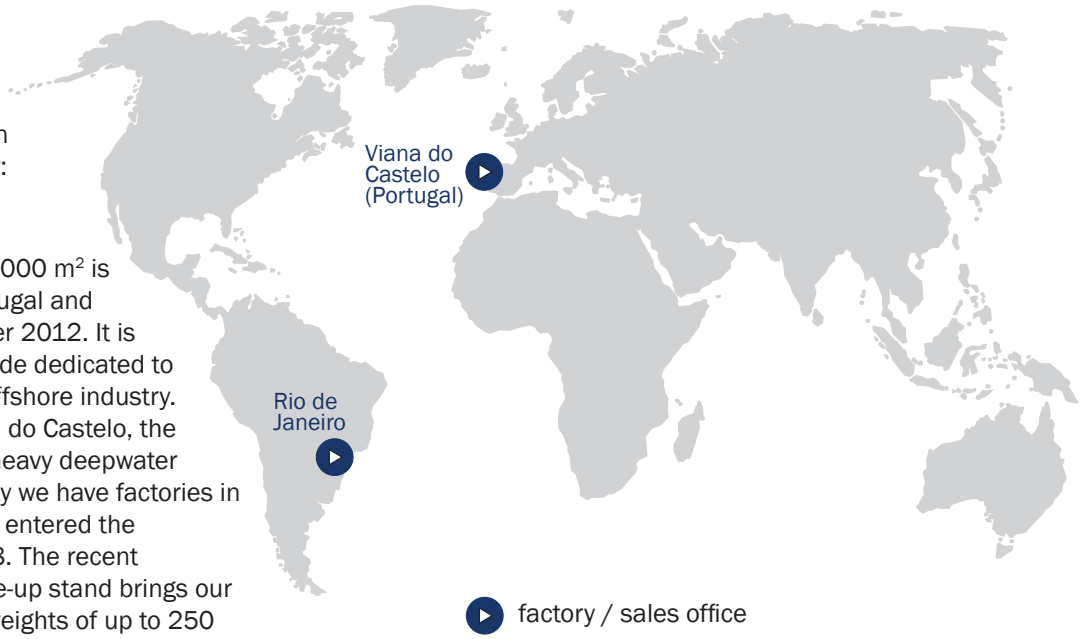

SINGLE POINT MOORING


SYNTHETIC TETHERS


DEEPWATER DEPLOYMENT


RENEWABLES

**LOCATIONS**
The most modern factories in the world dedicated to production of ropes for the offshore industry:




**Portugal**
The Lankhorst Offshore site of 6,000 m² is located in Viana do Castelo, Portugal and became operational in September 2012. It is the most modern factory worldwide dedicated to the production of ropes for the offshore industry. Positioned near the port of Viana do Castelo, the facility is well suited to produce heavy deepwater mooring ropes. Next to this facility we have factories in Maia and Paredes. The company entered the deepwater tether market in 1998. The recent commissioning of a new reel take-up stand brings our capacity to handle single piece weights of up to 250 tonnes gross (rope and reel).


**Lankhorst Euronete Portugal in Viana do Castelo**

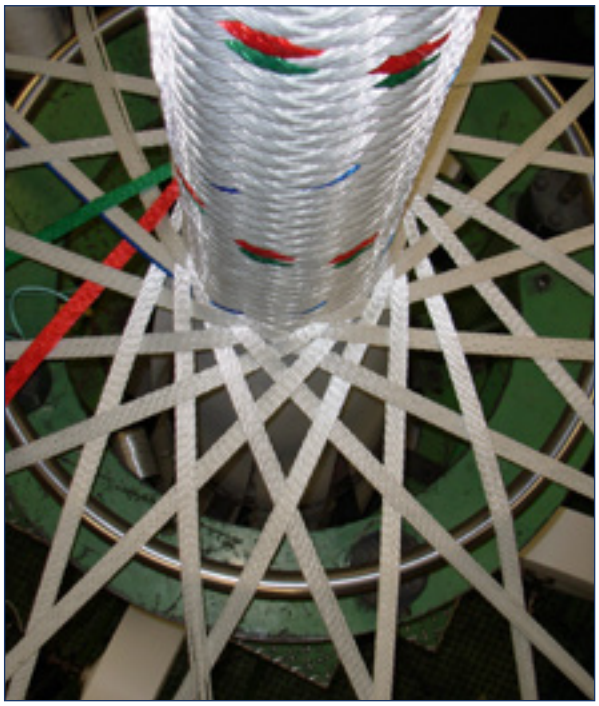
Lankhorst Euronete Brasil in Rio de Janeiro

# THE MOST MODERN FACTORIES IN THE WORLD DEDICATED TO PRODUCTION OF ROPES FOR THE OFFSHORE INDUSTRY

**Brazil**
The production facility of Lankhorst Euronete Brasil covers around 10,000m$^2$ in an 17,000m$^2$ property in the industrial site of Queimados in Rio de Janeiro with easy access to the ports of Rio de Janeiro and Sepetiba. The company started production of deepwater mooring ropes in 2012. Production capacity was doubled in 2015 with the addition of a complete new production line using state-of-the-art machinery.

**FACILITIES**
The factories are dedicated to the design, production and testing of offshore mooring ropes and specialty products such as deepwater installation ropes. Modern production and testing equipment permits all the following activities to be undertaken in-house:

- Stranding of base yarn into strands
- Braiding or twisting of strands into sub-ropes
- Application of soil ingress filters
- Production of braided jacket material (twisted yarn / cut resistant tape)
- Closing (over braiding) of sub-ropes into mooring ropes
- Length Measurement System (LMS) under tension up to 30 tonnes
- Length marking under tension in 75 m increments
- Axial (anti-twist) line marking
- Full scale proto-type testing
  - Break strength testing up to 1,200 tonnes
  - Tension-tension fatigue testing
  - Stiffness and elongation testing
  - Simulation of installation and “What If” scenarios
  - Cut resistant jacket testing
  - Linear density testing.



# LANKHORST OFFSHORE IN DEEPWATER MOORING

Deepwater moorings are different from other offshore rope applications. They are long term applications, typically 30 years, and under constant load. Unlike wire and chain mooring systems at shallower depths that rely on the weight of the mooring lines to hold the surface production unit on station, polyester rope taut leg mooring systems use the elasticity of the rope to provide the restoring force needed. Lankhorst Cabral 512® polyester rope is preferred by naval architects looking for a 'softer' mooring where the platform motions are more compliant and riser friendly.

Lankhorst Offshore has supplied over 1,000,000 meters of deepwater mooring ropes for some of the world's most demanding projects, including the Cascade & Chinook FPSO for APL/BW Offshore, Goliat FPSO for Eni Norge, Aasta Hansteen spar for HHI-Technip and Appomattox semi-submersible for Shell, as well as, the majority of projects for Petrobras in Brazil.

With each project, Lankhorst has developed manufacturing and rope technology innovations which have shaped the deepwater mooring industry. For Chevron's Tahiti spar moored at 1,219 m water depth in the GoM in 2008, Lankhorst introduced the industry's first Length Measurement System (LMS) for deepwater ropes with both practical and financial benefits. Accurate rope length allowed over $1.5M in top chain savings.

For deepwater moorings in the Norwegian Continental Shelf and North Sea, Lankhorst led the introduction of pre-laying mooring ropes during brief weather windows in the prevailing weather conditions. In this way, mooring lines are laid months ahead of the platform arriving on station and can be connected more quickly. The ropes feature an innovative filter system preventing seabed particles entering the rope leading to abrasion. Where there is a risk of damage to mooring lines from fishing trawlers, Lankhorst was the first company to develop a cut-resistant jacket designed to limit the external damage arising from trawler activities.

# LANKHORST OFFSHORE HAS MANUFACTURED AND SUPPLIED OVER 1,000,000 METRES OF DEEPWATER MOORING ROPES FOR MAJOR PROJECTS

**Lankhorst Euronete Brasil**

Lankhorst Euronete Brasil (LEB) is the largest manufacturer of deepwater mooring ropes primarily for the South American offshore oil and gas and maritime markets. In addition, LEB provides a wide range of offshore engineering services to ensure correct rope handling and compliance with installation procedures.

Over the past 5 years, the LEB manufacturing facility in Queimados, Rio de Janeiro, has completed manufacture of over 800,000m of deepwater mooring ropes for major offshore Brazil pre-salt oil field development projects for Petrobras, SBM Offshore, Hendrik Veder, APL, SOFEC, Teekay, and OOGTK. Projects have included: Petrobras P series FPSOs and DMA, FPSO Cidade de Maricá, FPSO Cidade de Saquarema, FPSO Cidade de Itaguaí, FPSO Cidade de Caraguatatuba, FPSO Pioneiro de Libra, FPSO Petrojarl and Atlanta project, and many more.

Technically, deepwater mooring has never been in better shape. Developments by Lankhorst Offshore in rope fibres and constructions, together with the mooring system insights gained over 20 years' experience, mean that many of the technical and deployment issues facing naval architects and installation contractors have already been solved, and if not, you can be sure we are well on the way to finding a solution.

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# KEY PROJECTS

Lankhorst Offshore have manufactured and supplied over 1,000,000 metres of deepwater mooring ropes for major projects such as:

**Lankhorst Euronete Portugal**

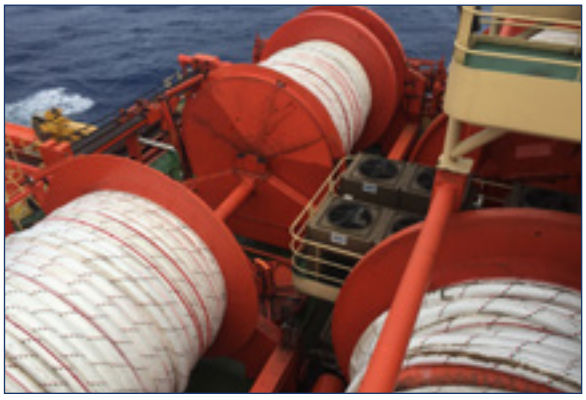
| | |
|---|---|
| • Tahiti spar for Technip | (Operator: Chevron) |
| • Thunder Hawk semi-submersible for SBM Atlantia | (Operator: Murphy) |
| • Cascade & Chinook FPSO for APL/BW Offshore | (Operator: Petrobras Americas) |
| • Lucius spar for Technip | (Operator: Anadarko) |
| • Goliat FPSO for Eni Norge Notes[1 & 2] | (Operator: Eni Norge) |
| • Heidelberg spar for Technip | (Operator: Anadarko) |
| • WIDP for Dana Petroleum | (Operator: Dana Petroleum) |
| • Aasta Hansteen spar for HHI-Technip[3] | (Operator: Statoil) |
| • Appomattox semi-submersible for Shell[4] | (Operator: Shell USA) |
| • Liza Destiny for SBM | (Operator: Exxon) |

Note 1 - Polyester ropes manufactured for the Goliat FPSO set a world record for the highest Minimum Breaking Load (MBL) ropes ever produced and tested.

Note 2 – First polyester ropes manufactured with cut-resistant jacket with Dyneema® fibre.

Note 3 - Polyester ropes manufactured for the Aasta Hansteen spar incorporated the first double layer cut-resistant jacket with Dyneema® fibre.

Note 4 – 2 ropes per reel with gross weight of 130 tonnes.



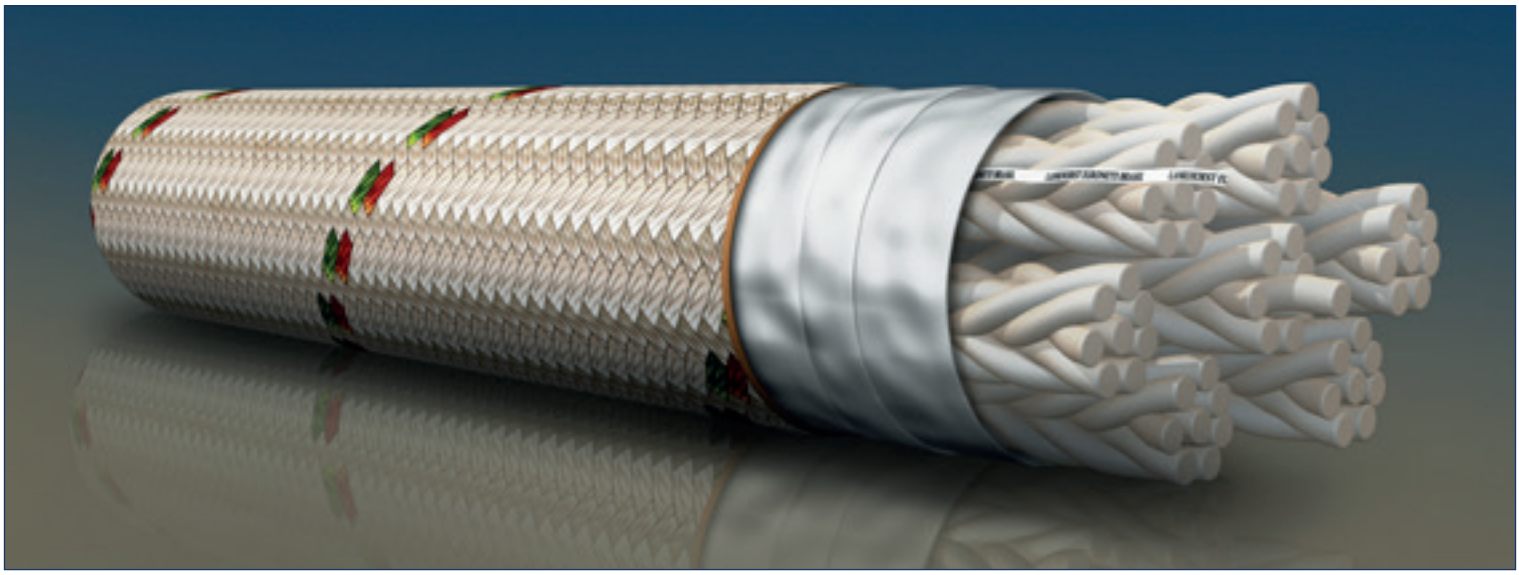
**Lankhorst Euronete Brasil**

| | |
|---|---|
| • P58 for Petrobras | (Operator: Petrobras) |
| • P62 for Petrobras | (Operator: Petrobras) |
| • FPSO Cidade de Maricá for SBM | (Operator: Petrobras) |
| • FPSO Cidade de Saquarema for SBM | (Operator: Petrobras) |
| • FPSO Cidade de Itaguaí for SOFEC/MODEC | (Operator: Petrobras) |
| • P74 for Petrobras | (Operator: Petrobras) |
| • FPSO Pioneiro de Libra for Odebrecht/Teekay | (Operator: Petrobras) |
| • Atlanta for Teekay Petrojarl | (Operator: Petrobras) |
| • FPSO Cidade de Caraguatatuba for SOFEC/MODEC | (Operator: Petrobras) |

For a more detailed project reference list contact deepwatermooring@lankhorstoffshore.com

# ROPE SELECTION

Lankhorst Offshore utilize a rope construction that is optimised for deepwater mooring applications.



## CABRAL 512®

CABRAL 512® polyester ropes are manufactured from high efficiency sub-rope cores laid parallel within an outer braided jacket. Each sub-rope is monitored during rope manufacture to ensure all sub-ropes have equal tension and length. Typically, CABRAL 512® ropes include 7 to 18 sub-ropes, each sub-rope being of a long lay length 12 x 1 construction, which gives a 100% torque free rope.

The design of this mooring rope consists of parallel laid yarns to construct the strands of the sub-rope cores which are also laid parallel within an outer braided jacket. Again, each sub-rope is of a long lay length 12 x 1 construction, which gives a 100% torque free rope.

| MBS | | | mass in | |
|---|---|---|---|---|
| mt | kN | diameter mm | air kg/m | water kg/m |
| 450 | 4,413 | 117 | 9.1 | 2.3 |
| 500 | 4,903 | 123 | 10.0 | 2.6 |
| 600 | 5,884 | 133 | 12.1 | 3.1 |
| 700 | 6,865 | 143 | 14.1 | 3.6 |
| 800 | 7,845 | 152 | 16.3 | 4.2 |
| 900 | 8,826 | 160 | 18.2 | 4.7 |
| 1,000 | 9,807 | 168 | 20.1 | 5.2 |
| 1,100 | 10,787 | 175 | 22.2 | 5.7 |
| 1,200 | 11,768 | 183 | 24.1 | 6.2 |
| 1,250 | 12,258 | 186 | 25.2 | 6.5 |
| 1,300 | 12,749 | 190 | 26.1 | 6.7 |
| 1,400 | 13,729 | 196 | 27.9 | 7.2 |
| 1,500 | 14,710 | 203 | 29.8 | 7.7 |
| 1,600 | 15,691 | 209 | 32.0 | 8.2 |
| 1,700 | 16,671 | 215 | 34.0 | 8.7 |
| 1,800 | 17,652 | 221 | 35.8 | 9.2 |
| 1,900 | 18,633 | 226 | 37.7 | 9.7 |
| 2,000 | 19,613 | 236 | 39.5 | 10.2 |
| 2,100 | 20,594 | 241 | 41.5 | 10.7 |
| 2,200 | 21,575 | 248 | 43.7 | 11.2 |
| 2,300 | 22,555 | 253 | 45.5 | 11.7 |
| 2,400 | 23,536 | 258 | 47.1 | 12.1 |
| 2,500 | 24,517 | 263 | 49.0 | 12.6 |

* Mass in Air is measured with the rope under a tension of 1% MBS

DNV·GL

APPROVAL OF MANUFACTURER CERTIFICATE

Lankhorst Euronete Portugal S.A.

**Particle Filter**

Filter elements are included between the outer jacket and load bearing sub-ropes. They are effective in filtering out particles greater than 5 microns whilst allowing free flooding of the rope. Seabed particles such as sand or clay in some conditions can cause damage to the sub-rope yarns when cyclically loaded. The filter acts as a barrier to stop these particles from entering the rope's core.

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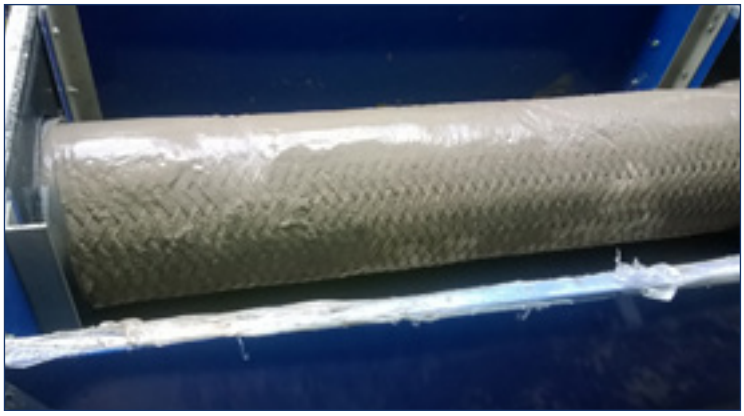
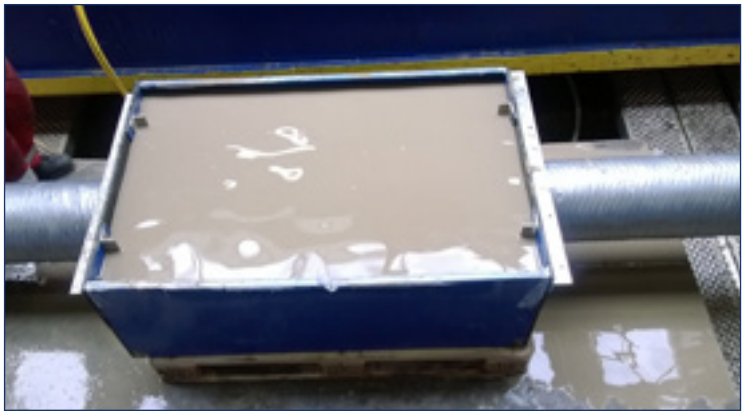
**Sea-bed Installation**

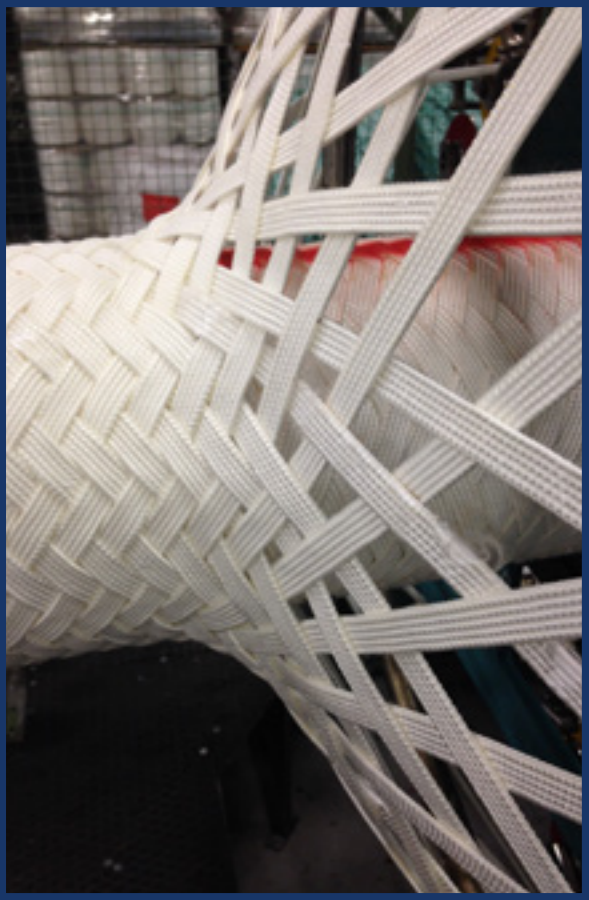
Filter systems can be provided to allow for ropes to be pre-installed on the seabed prior to vessel hook-up. In addition to our standard filter, Lankhorst has developed new filter technology that permits limited dynamic cycling during rope installation. In locations where the sea state can be challenging, the rope could see movement at the touch down point with the sea bed. At this point, it is possible for particles to be forced into the rope. Our filter technology stops this from occurring and has been approved on a previous project by DNV GL.





**Cut Resistant Jackets (CRJ)**

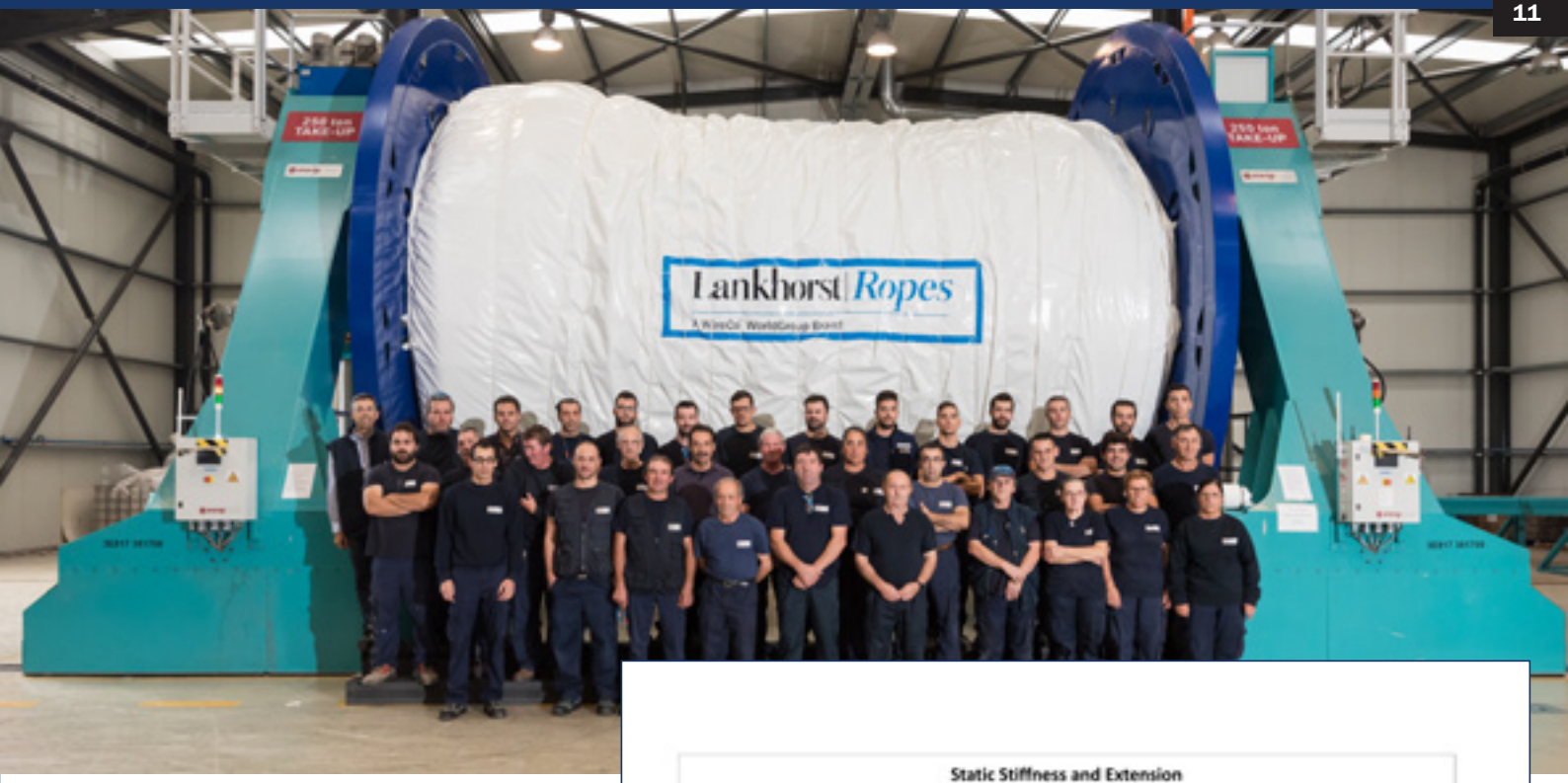
Polyester mooring rope systems operating in some offshore locations can be at risk from damage though contact with fish trawling wire ropes. Lankhorst Offshore has developed cut-resistant jackets using Dyneema® fibre especially for two mooring systems in Norwegian waters. As the number of polyester mooring systems increases so does the risk of failure due to external damage. Cut resistant jackets will gradually become more common. Lankhorst Offshore can now offer a proven cut resistant jacket for fibre ropes. In addition, we are developing a range of jacket designs combining optimum performance and cost effectiveness offering different performance levels to suit project-specific applications and locations.



**Mooring Line Length**

There is increasing pressure to reduce cost, risk and hook-up time during the mooring line installation phase of deepwater floating production systems. Longer rope lengths mean reduced numbers of segments and connecting hardware in a mooring line. Lankhorst Offshore's equipment can, in theory, manufacture ropes of infinite length. Recent project trends demand two rope segments per reel thus reducing the quantity of shipment packages and associated offshore handling times. Lankhorst Offshore's recent investment in a new reel take-up stand brings our capacity to handle package weights of up to 250 tonnes gross (rope and reel).

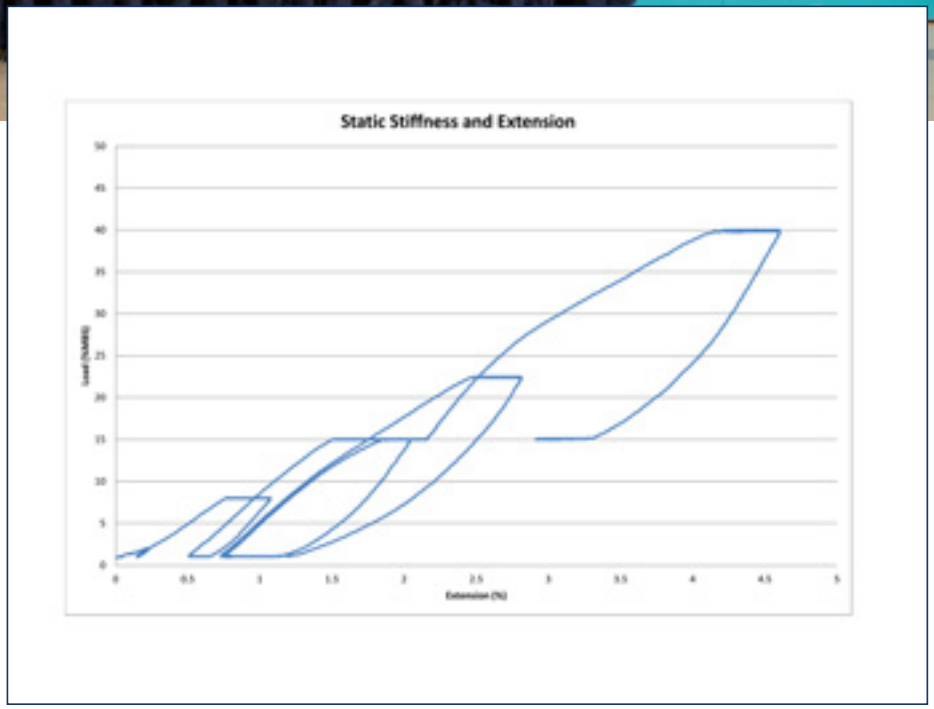
Maximum length is a function of the maximum reel weight and the linear weight of the rope which is dictated by the required breaking load.

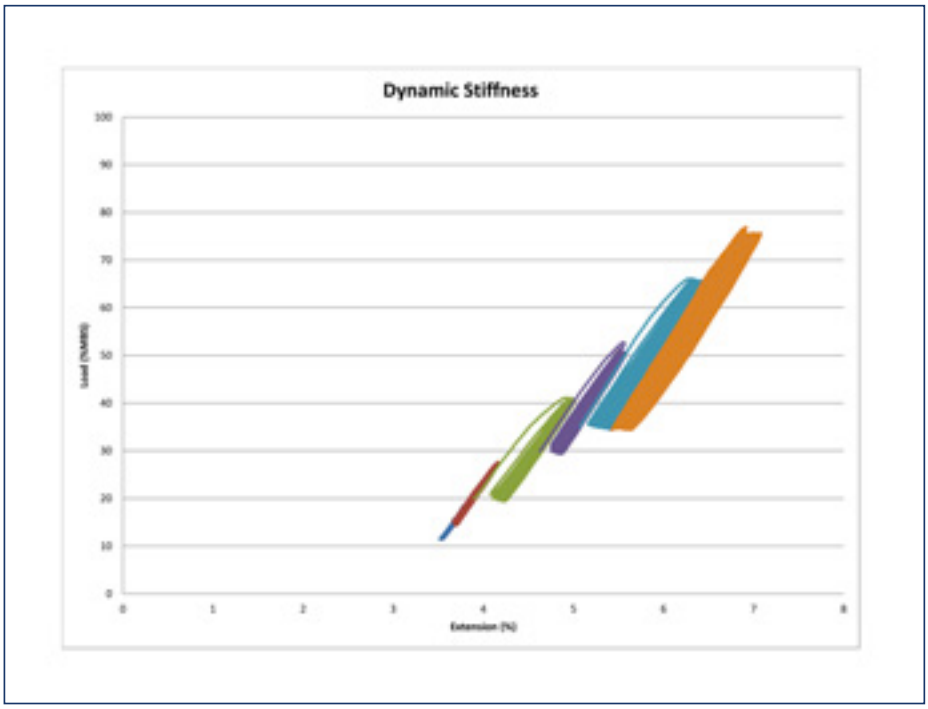



**Axial Stiffness**
Stiffness is normally divided into two categories, static stiffness and dynamic stiffness. Static stiffness is used to determine the extension of the rope from first order motions and calculate the offset of the vessel. Dynamic stiffness is used to calculate the peak loads in the mooring lines during second order motions of the vessel.

CABRAL 512® is the stiffest rope construction currently available in the market for deepwater mooring applications. It requires less constructional extension due to bedding in and lower overall elastic extension resulting in smaller platform offsets and the option to utilise lower pre-tensioning during installation.

In order to maximise the efficiency of the mooring system, Lankhorst recommends performing a stiffness test at an early stage. This stiffness test should incorporate static and dynamic loading scenarios and is performed on a sub-rope. Lankhorst can offer this service to our clients, please ask for further details.

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**Length Measurement**
Ropes for deepwater tethers are manufactured under a machine tension of approximately 1 tonne back tension. Lankhorst Euronete Portugal has installed a unique Length Measuring System (LMS) for length measurement under a controlled tension. The rope is pre-tensioned to 1% MBL (maximum 30 tonnes) for length measurement in 75m increments. Prototype testing typically starts from the same reference tension of 1% MBL. Length accuracy is achieved with a laser gun and mirror which is calibrated to 75m ±3mm. The rope is marked at each 75m increment and the marks, numbered sequentially (1=75m; 2=150m; etc), are recorded by digital camera, thus minimizing the risk of human error.

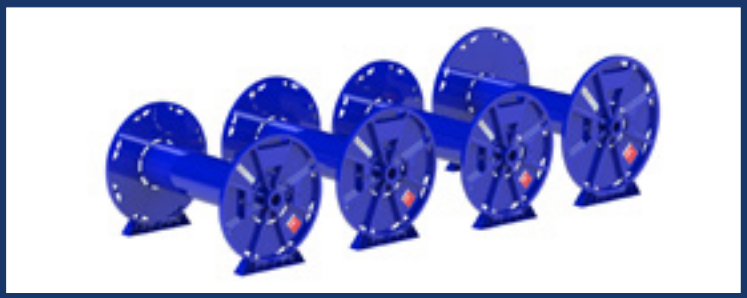
**Splicing and Terminations**
The CABRAL 512® rope construction is suitable for hand spliced terminations. The eye splice is engineered for high efficiency strength realisation. To achieve this, each sub-rope is allocated a pre-set position around the eye so that the load is shared equally by all the sub-ropes. Sub-ropes are colour coded for identification purposes so they have the same position throughout the rope, within each eye and are spliced to themselves. The eyes and splice area are protected with polyurethane. Digital photos at key stages of each splice are taken for quality control checks as well as recording the individual splicer's and team leader's name. These records form part of the final documentation pack.

Lankhorst provides a wide range of connection solutions for integration of mooring line components including:

- Polyester to polyester
- Polyester to chain
- Polyester to steel wire

We work closely with third party suppliers of mooring jewellery to ensure good interface connections.

**Storage Capacity**
Secure outside storage areas for finished product are available to clients at both our Portugal (LEP) and Brasil (LEB) facilities. At LEP there is 4,000m$^2$ with further storage available at the nearby port of Viana do Castelo. At LEB there is 1,200m$^2$ with an additional 42,000m$^2$ at our transport carrier partner located 1.5km from our factory in the same industrial park.



**Shipment Reels and Cradles**
Lankhorst Offshore supplies deepwater tethers spooled onto shipping reels/cradles that are designed to meet project specific requirements.

Reels and shipping cradles are typically designed to DNV GL Rules for Planning and Execution of Marine Operations and/or Noble Denton General Guidelines for Marine Transportations, as well as to customer and installation contractor specific requirements. Ropes can be spooled directly onto shipment reels from the production line with a back-tension of 5 tonnes on all rope layers. This will eliminate the rope burying into the rope layers beneath, which can happen with lower spooling tensions.

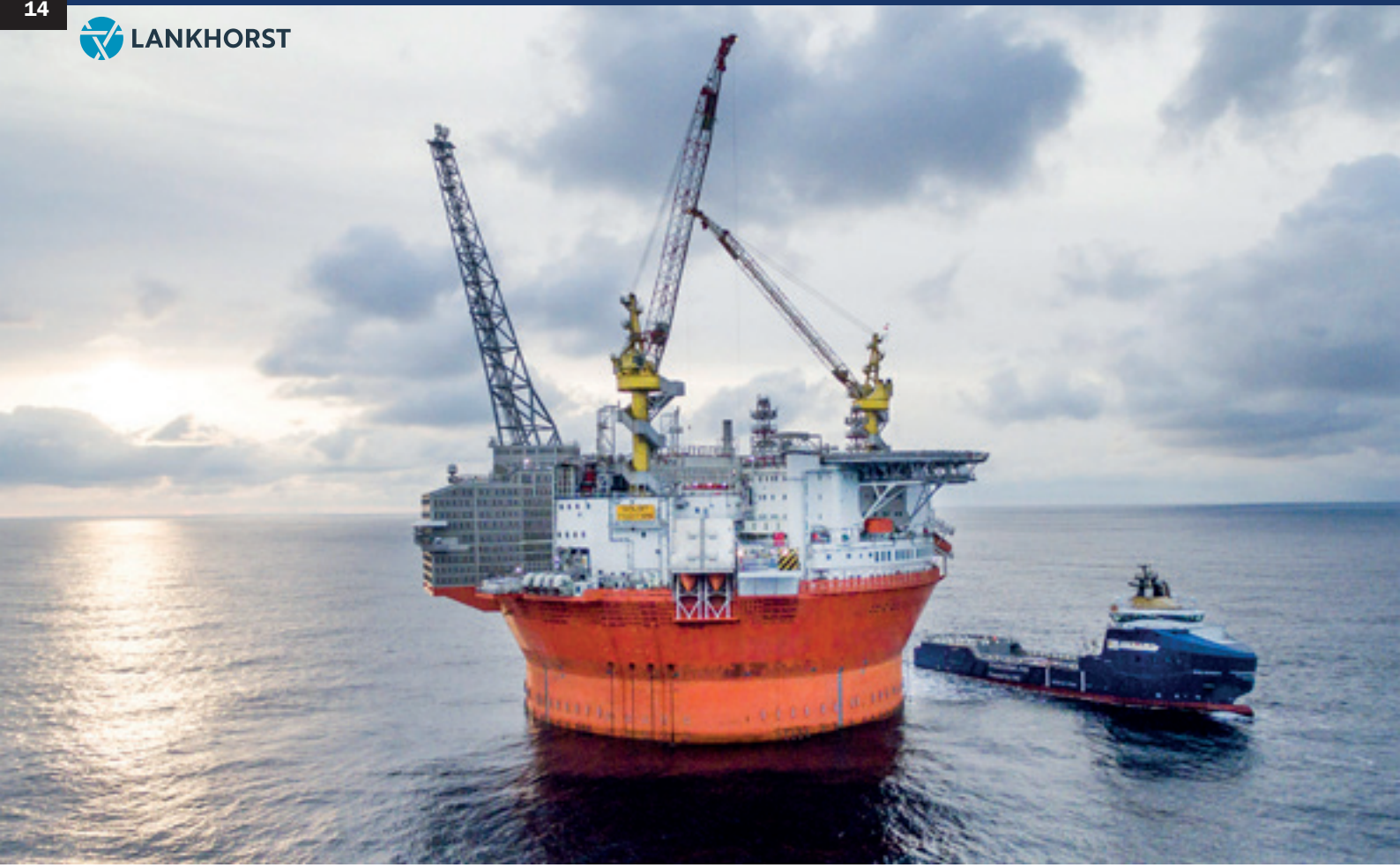
Lankhorst Offshore recommends that an installation contractor is consulted to ensure that interface issues between reels/cradles and installation equipment/vessels/transportation barges are addressed at an early stage in the project.

Typical reels/cradles are shown in the illustrations.


**Rigging**
Lankhorst Offshore certified lifting slings and spreader beams are also provided. Each reel can be pre-rigged with either steel wire or fibre rope slings. Wire rope slings are terminated with Flemish eyes and steel ferrules. A typical arrangement is shown above. For rigging projects, fibre rope sling sets can be supplied with a Calculated Breaking Strength.

**Packing and Transportation**
Ropes on reels are protected from the environment with specially fitted tarpaulins, which, if required, can be of fire resistant material.

Transportation of oversize reels to the port of shipment is carried out by low-load transport specialists.



**Connection Solutions**
It is now widely recognised within the industry and classification societies that the fibre tether is part of a mooring line system and cannot be certified in isolation. Thus the soft eye termination has to be tested with the connector that will join the soft eye of the rope to the next segment of the mooring line, whether this is a chain, wire, anchor or some other component.

Details of this connector, in particular the size and shape of the rope eye bearing surface have to be fully recorded. Substituting a different type and shape of end termination will render the rope certification invalid.

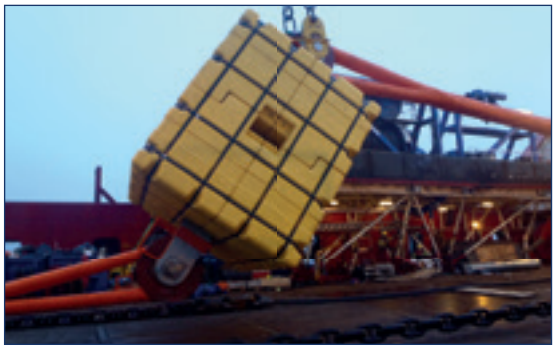
The choice of connector solution will often be driven by the installation methodology and the handling issues arising from the deployment scenario. The type of connector used for over boarding the stern roller of an AHV (Anchor Handling Vessel) will probably be different from a connector used for installation via a crane barge. The pre-tensioning methodology may also impact on connector design.

Regardless of installation issues, all connectors have the same basic requirements:

- To be lightweight
- To be small and compact
- To meet the design strength and fatigue life
- To be rope friendly and maximise splice efficiency.

Lankhorst Offshore can supply a range of connection solutions to meet the mooring system's needs in the form of thimble rolls, H-links, pear links and Y-links. We are continuously striving to develop and optimise the functional requirements of the connectors.

We recommend that you consult Lankhorst Offshore for advice on termination options to suit your mooring system at an early stage of engineering design.



**Testing and Joint Industry Projects (JIPs)**
Lankhorst Offshore has participated in the following JIPs and been instrumental in helping to shape the industry and the rules governing the deployment of fibre ropes in deepwater mooring applications:

- Engineers Design Guide
- Durability of Polyester Ropes
- Durability of Polyester Extension
- Damage Assessment Guidelines
- Design Practice Guidelines
- Insert JIP
- Safe Service Life (Arelis)
- FPS Mooring Integrity
- OCIMF 2000 Hawser Guidelines
- API RP 2SM Revision
- RPSEA JIP
- Arctic Mooring JIP.

In addition to the JIPs listed, we also participate in privately sponsored research projects and other JIPs specifically related to other fibre rope mooring applications, chain and mooring jewellery.

Lankhorst Offshore has a wealth of test data from these JIPs, and in-house testing, as well as from numerous test programmes undertaken at DNV GL Bergen laboratories and FURG-POLICAB in Brasil.

Lankhorst Offshore has invested in a 1,200 tonne MBL x 25m long test machine to enhance the service provided to our clients by enabling:

- Quicker response time to certify products
- Faster R&D development programmes
- Client specific testing programmes
- Simulation of installation and “What If” scenarios
- Reduce data errors with longer test samples.

The test machine is fully automated for cyclic testing as well as break load testing and is calibrated to class 1 level.

**Project Management**
All deepwater mooring (DWM) projects follow the established framework of the Association of Project Management Body of Knowledge which defines the key principles for project management. During the bid phase, a Lankhorst Offshore project team is assigned made up of representatives from the key disciplines required for the contract. The project team is led by a specialist DWM Project Manager. The project team are responsible for the successful delivery of the contract. Key to the management of any project is the Project Management Plan (PMP) and, since every project is unique, Lankhorst Offshore tailors the PMP in accordance with each projects requirements. The PMP is the governing document for the execution of the project and defines how the project is undertaken, monitored and controlled. This process driven methodology to the management of projects ensures consistency, not only throughout the project, but across all Lankhorst Offshore’s DWM projects.

# POLYESTER ROPE FOR PERMANENT MOORING

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**LANKHORST EURONETE PORTUGAL, S.A.**

Rua Fornos da Cal no 321
(near Avenida Do Cabedelo)
Darque
4935-226 VIANA DO CASTELO

Rua da CERFIL (Cap. Gramaxo)
4475-468 NOGUEIRA DA MAIA
PORTUGAL

T: +351 229 619 200

**LANKHORST EURONETE BRASIL, INDÚSTRIA E COMERCIO LTDA.**

Rua Minas Gerais 1920,
Distrito Industrial de Queimados
CEP 26.373-280 – Queimados
RIO DE JANEIRO
BRASIL

T: +55 21 2663 9000

E: deepwatermooring@lankhorstoffshore.com


**WWW.LANKHORSTOFFSHORE.COM**

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