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ADDENDUM

Page iii, replace Foreword with:

FOREWORD

API RP 2SM is under the jurisdiction of the API Subcommittee on Offshore Structures. The main purpose of this document is to provide guidelines on the use of synthetic fiber ropes for offshore mooring applications. The secondary purpose of this document is to highlight differences between synthetic rope and traditional steel mooring systems, and to provide practical guidance on how to handle these differences during system design and installation.

Thus, this document covers the following:

a. Design and analysis considerations of mooring system.
b. Design criteria for mooring components.
c. Rope design.
d. Rope specification and testing.
e. Rope manufacture and quality assurance.
f. Rope handling and installation.
g. In-service inspection and maintenance.

This Addendum updates the current edition of API RP 2SM with the latest knowledge on key issues, particularly for polyester mooring rope. Each numerated section below references the existing section and notes the changes to the document. Also included in this Addendum is a new Appendix on minimizing fiber rope damage during installation.

Suggested revisions are invited and should be submitted to the Director of the Standards Department, Upstream Segment, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

Page 4, Section 3.2, replace last sentence with the following:
"The differences from steel wire/chain mooring systems include: non-linear stiffness, different handling procedures, necessity to keep fiber rope away from fairlead, necessity in some cases to keep fiber rope away from sea floor, axial compression fatigue considerations for aramid rope, and creep rupture considerations for HMPE rope."

Page 4, Section 3.3.3, replace entire section with the following:
"Fiber ropes are constructed from fiber materials that display visco-elastic properties. The rope exhibits a non-linear behavior that is dependent on mean load, load range, rate of loading and load history. After the rope has been tensioned to allow bedding-in, and cyclic load and relaxation has occurred, the stiffness changes with mean load and load range. The rate of loading will also have an effect on dynamic stiffness. As the rope is loaded beyond its previous maximum load, it undergoes a permanent increase in length. The combination of increased length and change in stiffness can result in a softer mooring system.

During initial installation and tensioning, and prior to bedding-in and relaxation, it is difficult to define stiffness. In this case the static stiffness can be bounded by the minimum (lower post installation stiffness) and maximum (higher post installation stiffness) values. Similarly, the dynamic stiffness can be bounded

by the intermediate and storm stiffness values. This simplified approach, discussed further in 4.6.4, may be used in lieu of a more appropriate stiffness model that matches the non-linear, time dependent nature of polyester rope.

For moorings with large synthetic ropes, the installation tension is generally much lower than the maximum design tension. When the mooring line is loaded beyond its installation tension, there are two effects that can change the performance of the mooring system. First, the synthetic rope will lengthen due to additional bedding-in or fiber elongation. Second, the static and dynamic stiffnesses of the rope will increase. The overall effect of the increase in line length combined with the increase in mooring line stiffness may be a reduction in effective mooring system stiffness at low loads. Conversely, the mooring system stiffness may increase if the base fiber exhibits low elongation.

Platform offsets are a primary concern for risers. Proper evaluation of offsets requires detailed information on the permanent elongation (bedding-in) and static stiffness of the synthetic rope over a range of tensions. Furthermore, the permanent elongation and static stiffness data used for mooring performance evaluation need to be representative of the planned mooring operation, including installation tension, pretension and mooring line length management.

Additional consideration should be given to other potential influences on global system stiffness. These influences include: rope age and usage history, manufacturer and construction, and base fiber properties.

A general indication of the effects of creep is given by yarn data from other sources [2]. Some newer HMPE fibers show reduced creep, and creep in rope is less than creep in yarn.

Permanent elongation—whether due to creep or construction stretch or other mechanisms—may lead to the need to adjust the length of the mooring lines. In most fibers, creep rate reduces with time and is approximately the same for equal increments of log (time), e.g., creep over 1 decade of log (time)."

Page 5, Section 4.2.1, replace the second sentence with the following:
"Polyester and aramid ropes do not have potential creep rupture problems."

Page 8, Section 4.6.3, replace the first paragraph with the following:
"Some polymer based fiber ropes are subject to creep, potentially leading to creep rupture. HMPE ropes may experience significant creep, leading to creep rupture. Polyester and aramid ropes are not subject to significant creep at loads normally experienced in mooring applications and thus are not normally subject to failure due to creep rupture."

Page 9, Section 4.6.4.1, replace entire section with the following:
"Stiffness is a measure of resistance to deformation. In this document, it refers to axial stiffness and is defined as incremental rope tension divided by incremental rope strain. It thus equates both to spring constant times length (k x L) and modulus times rope area (EA), and are used interchangeably within this document.

The minimum and maximum linearized static stiffness values that are recommended for use in a simplified representation of fiber rope stiffness are defined as:

- Lower Post-Installation Stiffness: the secant stiffness over the load or strain range of interest in quasi-static loading immediately after installation and prior to any significant environmental events that lead to rope tension higher than the installation load. It is the stiffness which corresponds to the extensibility of the mooring lines under quasi-static load once the Minimum Installation Tensioning (see 8.3) has been performed during installation.
- Higher Post-Installation Stiffness: the secant stiffness over the load or strain range of interest in quasi-static loading immediately after extreme loading approaching the maximum design tension.

The minimum and maximum linearized dynamic stiffness values that are recommended for use in a simplified representation of fiber rope stiffness are defined as:

- Intermediate Stiffness: represents the secant stiffness in cycling about the mean load during normal operating conditions.
- Storm Stiffness: represents the maximum secant stiffness in cycling about the mean load during the maximum design storm to the cyclic strain limits predicted in the maximum design storm. This stiffness will result in the largest loads being generated in the mooring lines as the platform moves compliantly in the storm.

All stiffness values should be calculated from a reference length as defined in 6.2.7.2 prior to the cycle in question and not from the original rope length."

Page 10, Section 4.6.4.2, replace entire section with the following:
"Typical values of static and dynamic stiffness data for fiber rope mooring lines, based on polyester, aramid and HMPE ropes, are given in Table 4.6.4.2 [2]. To a first approximation, these stiffness values will scale with the breaking strength of the rope. Table 4.6.4.2 only gives typical values for indicative or comparative purposes only and shall not be used for design. Actual values as determined by the test methods in Section 6 should be used in design and analysis."

Page 10, Section 4.6.5, replace entire section with the following:
"Total elongation of the fiber rope assembly throughout the mooring design life should not lead to creep rupture. Elongation in fiber rope assemblies results from bedding-in of the rope structure and terminations and from both instantaneous extension and creep in the yarns. It will occur in all fiber rope assemblies under both steady and cyclic loads.

Rope manufacturer should provide the designer and installer the information necessary to estimate the amount of elongation due to bedding-in and creep expected during the initial installation period and during the design life of the project based on expected mean and maximum design loads. Bedding-in and creep elongation estimates should be based on rope test data. The designer should calculate the effect of increase of line length in order to provide appropriate mooring line length management. Length management may be achieved through winching or the removal of relatively short sections (e.g., 100 ft – 250 ft).

For polyester and aramid ropes, the continuing elongation due solely to creep is not expected to exceed 1% – 2% during the life of a typical offshore installation. For HMPE and nylon ropes creep elongation can be much higher and care should be taken to acquire test data that demonstrates adequate resistance to elongation and creep rupture."

Page 13, Section 4.6.7.3, replace entire section with the following:
"Axial compression fatigue is not a concern with polyester and HMPE fiber ropes.

Axial compression fatigue may occur in an aramid rope when it experiences many cycles to a low trough tension. Precautions should be taken to keep sufficient tension on aramid rope mooring lines, especially on leeward lines during storm conditions. Axial compression fatigue damage can be avoided with proper rope design and use. The provisional guideline is to not permit aramid fiber rope mooring lines to experience more than 500 cycles below a trough tension of 10% MBS over the life of the mooring line. In the context of evaluating axial compressive fatigue damage, if the tension in the line is below the 10% MBS threshold at any time in the cycle, then that cycle is counted toward the design limit. The user may always choose to utilize rope testing to establish compression fatigue performance, which can supersede the provisional guideline outlined above."

Page 13, Section 4.6.7.3, remove Table 4.6.7.3.

Page 13, Section 4.6.10, add the following sentence to the end of the section:
"Additional comments on salt crystallization are contained in 8.2.10."

Page 14, Section 5.3.2, replace entire section with the following:
"The previous requirement for minimum tension and maximum number of low-tension cycles is no longer applicable to polyester fiber ropes as they are not susceptible to axial compression fatigue.

As a general guideline for aramid ropes during installation and throughout the service life of the mooring line, tension should not drop below 10% MBS more than 500 times. Fiber ropes may be designed to sustain more cycles or lower tensions than indicated above before severe strength loss occurs. However, test data should be provided for justification of relaxing this general guideline."

Page 14, Section 5.3.4, add the following sentence to the beginning of the section:
"The following discussion only applies to HMPE rope mooring lines."

Page 15, Section 5.4.2, replace entire section with the following:
"As discussed in 3.3.3, the load-elongation properties of fiber ropes are non-linear and load rate dependent. The unloaded length and stiffness properties of the rope depend on load history. Therefore, a proper representation of the fiber rope axial stiffness requires a non-linear stiffness, time dependent model and the definition of the unloaded length of the fiber rope. In the simplified linearized approach, the unloaded length, dynamic storm stiffness, and static lower post-installation stiffness as defined in 4.6.4.1 can be used to estimate mooring loads and vessel offsets. A sensitivity study should be conducted to investigate whether these stiffness values are adequate to identify the maximum and minimum line tensions and vessel offsets. The actual stiffness values used in the mooring analysis should be derived from rope testing as described in 6.3.

For MODU moorings, it is generally sufficient to use the static lower post-installation stiffness for calculating offsets and the upper-bound dynamic storm stiffness for calculating line tensions. Use of these values for stiffness should provide conservative estimates of vessel offsets and mooring line tensions.

For permanent moorings, it is recommended to use more detailed information on static and dynamic stiffnesses in order to better estimate vessel offsets, line tensions, and fatigue damage. Use of the static lower post-installation stiffness and upper-bound dynamic storm stiffness may result in overly conservative estimates of vessel offsets, mooring line tensions, and fatigue life. Thus, this simplistic approach may lead to increased mooring line size, capital cost and installation cost. The designer should also be cognizant of the impact of permanent rope elongation when working with non-adjustable mooring systems (as discussed in 3.3.3)."

Page 15, Section 5.4.4, add the following sentence to the beginning of the section:
"The following discussion only applies to HMPE rope mooring lines."

Page 16, Section 5.4.6, add the following sentence to the beginning of the section:
"This analysis is only necessary for aramid rope mooring lines."

Page 22, Section 6.3.8, add the following sentence to the beginning of the section:
"This test is only necessary for aramid rope mooring lines."

Page 25, Section 8.1, add the following sentence to the end of the section:
"For additional guidance on handling of fiber ropes, see Appendix G."

Page 27, Section 8.3.2, add the following sentence to the beginning of the section:
"This requirement only applies to aramid rope mooring lines."

Page 27, Section 8.3.4, add the following paragraph at the end of the section:
"Fiber ropes with proven filter barriers and jackets are allowed to come into contact with the seabed. If fiber ropes are used in applications with seabed contact, they should be specifically designed for such use. The mooring designer and rope designer shall address, as a minimum, the following items:

- site survey, including rock outcroppings and soil properties such as abrasiveness and softness,
- damage to jacket and filter barrier during installation due to abrasion with hard soils,
- impact of cyclic motion on soil particle migration through the filter barrier,
- on-bottom stability for ropes abandoned on the seabed prior to installation,
- inspection issues. See API RP 2I."

Page 28, Section 8.3.8a, add the following sentence to the beginning of the section:
"The minimum tension requirement only applies to aramid rope mooring lines."

Page 29, Section 8.3.8c, add the following sentence to the beginning of the section:
"The minimum tension requirement only applies to aramid rope mooring lines."

Page 32, Section 9.3.3, add the following sentence to the beginning of the section:
"See API RP 2I for additional discussion on fiber rope inserts."

Page 34, Section 9.5.3, add the following sentence to the beginning of the section:
"The avoiding compression fatigue recommendation only applies to aramid rope mooring lines."

Page 45, Appendix B, add the following section to the beginning:

B.0 General

The mooring system designer and the rope manufacturer should specify and execute a rope test program which provides adequate information on and gives adequate assurances of rope performance characteristics.

Page 51, Appendix D, add the following sentence to the beginning of the section:
"This test only applies to aramid rope fiber ropes."

Add the following Appendix:

Appendix G—Strategy for Minimizing Fiber Rope Damage during Installation

G.0 General

Installation of fiber rope begins with staging. While stored prior to deployment, load-bearing cores of fiber ropes should be protected from dust, UV rays, and moisture if possible. This protection can be accomplished by storing fiber ropes on reels within an enclosed structure or providing adequate tarps or covers to protect the ropes.

During any handling of fiber ropes, efforts should be taken to limit the amount of oil and grease exposure.

G.1 Installation Using Anchor Handling Vessel

G.1.1 INSTALLATION VESSEL

Installation vessels must also be prepared or inspected prior to loading and deployment of fiber ropes. There are several key areas on conventional installation vessels that should be prepared. The stern roller should be inspected for any sharp areas or potential areas where the fiber rope or jacket could get snagged or cut. The stern roller should also be checked to see that it is operating properly and rolls under minimal load. The vessel work deck should be cleaned and inspected for any sharp objects or snag points. (One particular item to watch for is old sea fastenings, which may not have been fully removed from the deck.) All winch or deployment drums should be inspected for sharp objects or snag points, including storage reels if they are to be used during any step of the installation. The level winds should be inspected to see that they are working properly and have no sharp surfaces.

G.1.2 LOADING FIBER ONTO VESSEL DRUMS

Once the vessel has been inspected and prepared, the fiber rope can be loaded. Proper guides should be utilized to load the fiber rope from the shipping or storage reels onto the vessel drums. If any fiber rope transfers will take place offshore, properly designed rollers should be utilized to maintain minimum bend radii specified by the rope manufacturer and API RP 2SM. During loading, the installer should conduct a visual inspection of the rope to ensure that the rope is in good condition. (Inspect any jacket or terminations for visible damage.) All termination and connecting hardware should be inspected for sharp corners or snag points during loading.

Any terminations or sections of the fiber rope which have polyurethane coatings should be visually inspected to ensure that the coatings are intact and fit for purpose. A visual inspection should be conducted to check for any visible sign of splice damage.

During loading onto the vessel drums, it is important to load the fiber rope with sufficient back tension and as densely as possible to protect against the rope “cutting in” on itself during deployment.

G.1.3 ROPE STOPPING TECHNIQUE

With an installation plan in place, check any fiber rope stopping devices or methods for suitability and proper operation. Also check any interfaces these devices or methods have with connecting hardware. The objective is to ensure the safety of personnel while using proven stoppering techniques that do not damage the fiber rope.

G.1.4 ROPE DEPLOYMENT

For most fiber rope installation, the load the fiber rope will see during the deployment should not exceed 10% of the design minimum break load (MBL) of the rope; this is especially true for new rope. If installation requires loading beyond 10% of the rope’s MBL, a higher density and back tension should be

used when loading the rope on the installation drums. To reduce the installation loading, use of subsea mooring connectors may be needed to limit the load on the fiber rope during deployment. During deployment, the rope should be monitored at the stern roller to check if the stern roller is operating properly and causing no damage to the rope.

G.1.5 CONTACT WITH SEAFLOOR

Provided that adequate documentation exists for the performance of the filter barrier, fiber ropes may be laid on the seabed prior to hookup to the vessel. The area should be surveyed for rock outcroppings and other geohazards that may make this option ill-advised.

Upon each recovery of a fiber rope laid on the seabed, the rope should be visually inspected for any signs of jacket damage and filter barrier damage. If the jacket has been damaged, the rope should be further inspected to see if the filter barrier is intact. If the filter barrier is not intact, then the rope should be removed from service and inspected in closer detail to determine if soil or other particles have moved into the load bearing fiber cores. If the load bearing fiber cores have not been affected by soil or other particle ingress, then the rope filter barrier and jacket may be repaired and returned to service. If the rope has experienced ingress of particles at the damaged location, additional sections of rope at least 5 diameters on each side of the damaged location shall be inspected. If this inspection reveals no particle ingress beyond this area, then that length shall be removed. If inspection reveals particle ingress on one or both ends of the rope, additional inspection will be performed, at 5 diameter intervals away from the end where particle ingress is found, until no particle ingress is found. This inspection will determine the affected area that must be removed and then the rope may be re-terminated for further use.

For hard seabed conditions that may result in damage or abrasion of the jacket, fiber ropes should not be allowed to contact the seabed.

G.1.6 CONNECTING THE PRESET MOORING

For preset fiber rope connection operations, rope tensions should be actively managed to minimize high stress being placed on any ropes over tight bending radii.

Extra attention should be paid to ropes near boat rudders or other low hanging parts of the installation vessel. (This can be accomplished through calculations and knowledge of the vessel architecture below the waterline.)

G.2 Installation Using Deepwater Construction Vessel

While Anchor Handling Vessels (AHVs) account for a large number of fiber rope deployments, Deepwater Construction Vessels (DCVs) are sometimes utilized to install larger diameter fiber ropes for permanent facilities. Use of DCV requires many of the measures recommended for AHVs to protect against fiber rope damage.

G.2.1 CONTACT WITH PROBLEM AREAS

The same precautions taken for AHVs should also be taken for DCVs. These include inspection and removal or mitigation of any sharp or snag points that may damage the fiber rope during any stage of installation. Extra precautions should be taken to reduce the chance of fiber rope damage in welding areas or during other activities that can cause fiber rope damage. Protective layers or barriers could be utilized to keep the fiber rope from coming into direct contact with problem areas. As with AHV deployment, the use of fiber work ropes should also be considered for handling of the fiber rope on the DCV where there can be direct work rope to fiber mooring rope contact.

G.2.2 DEPLOYMENT WITH LARGE WINCH

The major difference is the size of a DCV deployment winch, which commonly holds a much larger quantity of fiber rope compared to an AHV winch. This means that the length can be greater than that

utilized for an AHV deployment. Care should be taken to select a suitable fiber rope length such that use of the planned installation vessel is most efficient, but also allows for safe transportation and spooling of the fiber rope to the deployment winch. Since at least some of the fiber rope reels will have to be spooled onto the deployment winch offshore, special consideration should be taken in the transportation reel. The transportation reels may have to meet certain dimensional requirements to interface with the DCV's on-board spooling units and conform to particular deck arrangements. Sea-fastening considerations for the transportation reels should also consider the use of bolt-style clips to reduce the requirement and risk of welded sea-fastenings in close proximity to the fiber rope.

As with AHV installation, fiber rope packing on the DCV winch is another important consideration.

G.3 Additional Considerations

G.3.1 ROPE STIFFNESS AND LENGTH

Fiber rope stiffness and elongation during the deployment process must also be considered. It is important to get accurate elongation and stiffness data from the rope manufacturer in order to properly plan the installation operation.

The shipping reels should be clearly and correctly labeled to allow for easy identification of rope segments and lengths to reduce the chance of improper installation.

G.3.2 ROPE TWIST

Fiber ropes utilized in permanent moorings may have twist monitoring stripes. These stripes should be visible on the deployed section of the fiber rope and should be monitored during spooling operations to ensure acceptable twist is maintained.

G.3.3 TERMINATION HARDWARE AND COATING

It is common to coat the splice region of the rope with polyurethane to protect it from handling/installation damage. These coatings should be adequately applied and inspected such that connection activities between fiber rope segments can be executed with minimal risk of damage. Care must be taken when applying the coating to make sure the build up does not hinder installing the spool. Using a mold may be desirable so that the polyurethane is consistent and fits properly in the spool.