Rio de Janeiro, January 2, 2024.

PETRÓLEO BRASILEIRO S. A. – PETROBRAS

Market Consultation
Request for Information (RFI)

Att. Commercial Board

Ref.: Request for Information for companies supplying Swiveled Symmetrical Bending Stiffener.

Dear Sir/Madam,

PETRÓLEO BRASILEIRO S.A. - PETROBRAS, through CENPES/GIT/MNCI (Contracting of R&D, Technologic, and Specialized Technical Services), using information technology resources, through the Electronic Purchasing Portal Petronect – Procurement Negócios Eletrônicos S.A. (hereinafter called "Electronic Portal"), which electronic address is www.petronect.com.br, is performing a Technological Order (ETEC) Survey and aims to obtain information from mapped companies that have already participated in this type of contracting with Petrobras, in order to promote improvements in your supply process.

These valuable insights will give us significant support in future improvements in Contracting using this ETEC modality.

The study Petrobras is performing is on the **Swiveled Symmetrical Bending Stiffener**, which aims to locally increase the rigidity of the flexible pipe to progressively reduce the curvature and, consequently, the stresses imposed on the pipeline, in order to meet specific demands for the installation of risers in deep waters. This bending stiffener absorbs the bending moments acting on the pipeline by bending a double polyurethane cone pivoted to a stationary structure. Therefore, there is a smooth transition between the tubular body of the pipeline and its termination.

We have identified your company as a potential supplier and would like you to help us by completing and sending this RFI (Technological Order Survey), which must be completed by 01/23/2024. It is desirable all requested information be completed, although it is not mandatory. This Survey may be answered by a single supplier or by a group of them, in which case, information from all components of the group is requested.

It should be emphasized that the information to be sent, in response to the questions asked through this Survey, will be treated confidentially and must be truthful. PETROBRAS reiterates it ensures the confidentiality of the information provided by suppliers in this Survey, which will be used for its own use and will not be disclosed to third parties.

1. **DELIVERY AND PRESENTATION OF INFORMATION**

Answers to the questions presented must be filled out directly in the forms available via the link: https://forms.office.com/r/JD6G94Ggm9

- Start Date: 01/02/2023, at 05:00 PM
- End Date: 01/23/2024, at 05:00 PM

IT IS NOT NECESSARY TO ATTACH ANY DOCUMENTS TO THE PETRONECT PORTAL, just fill in the form in the link provided above. For prior knowledge, we are attaching the content of the questionnaire to be answered.

2. **CLARIFICATIONS:**

Questions about this Survey process must be sent through the “Collaboration Room,” available on the Opportunity of Petronect Portal, by 01/19/2024. The answers will be published in the “Collaboration Room.”

3. **GENERAL NOTES:**

To participate in this Survey process, the interested party can register in the Opportunity of Petronect Portal. If it is not registered on the Petronect Portal, the system will provide instructions on how to obtain the access key.

If the participant is not interested in registering with Petronect, contacts regarding this RFI can be made by email to cc-RFIPetrobras@petrobras.com.br with the subject “RFI: **Swiveled Symmetrical Bending Stiffener.”**

PETROBRAS is not responsible for any errors when sending emails or for accounting for responses that differ from the standards required here.

Problems with connection and/or questions about the Petronect Portal:

- Capitals, metropolitan regions, and calls originating from cell phones: 4020-9876;
- Other regions: 0800 282 8484;
- United States 1 866 791-9432;
- Other countries +1 713 808-2599.
- or via WEB SERVICE, available on the PETRONECT portal under the CONTACT US option.

Time Reference: The times listed in “Start Date” “End Date” refer to the time zone configured for the user accessing the Opportunity. This time zone is indicated in the “Basic Data” tab, in the “Time Zone” field. Example: ZBRRJ (BR of Brazil, RJ of Rio de Janeiro). The time zone can be changed in the “Registration” tab, and it is the user's responsibility to keep it updated if the workplace changes.

Note: Scheduled dates and times are estimated and may change. It is the bidder's duty to monitor the effective date on the Petronect Portal, which will prevail for all purposes.

Best regards,

Petróleo Brasileiro S/A - Petrobras
Research and Development Center (CENPES)
Technological Innovation Management
Technology business models and connections for innovation
CENPES/GIT/MNCI

RFI: **Swiveled Symmetrical Bending Stiffener**

Description

PETROBRAS is performing a study on Swiveled Symmetrical Bending Stiffener, which aims to locally increase the rigidity of the flexible pipe to progressively reduce the curvature and, consequently, the stresses imposed on the pipeline, in order to meet specific demands for the installation of risers in deep waters. This bending stiffener absorbs the bending moments acting on the pipeline by bending a double polyurethane cone pivoted to a stationary structure. Therefore, there is a smooth transition between the tubular body of the pipeline and its termination.

* Mandatory

The intended solution must meet the requirements and restrictions described below:

Specification of Services and Questions

1

Current bending stiffeners transfer considerable loads to the Bell Mouths. In the case of installing platforms in deeper waters, the risers are resized using new calculation criteria, which may result in the need for large bending stiffeners that could not be structurally supported by the Bell Mouth. Therefore, it is essential to develop a new type of stiffener that reduces the loads imposed on Bell Mouths.

This new type of swiveled symmetric bending stiffener aims to locally increase the rigidity of the flexible pipe to progressively reduce the curvature and, consequently, the stresses imposed on the pipeline. The bending stiffener absorbs the bending moments acting on the pipeline by bending a double polyurethane cone pivoted to a stationary structure. Therefore, there is a smooth transition between the tubular body of the pipeline and its termination.

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1. Possible solution proposed by PETROBRAS.

The solution proposed and studied by Petrobras will be presented below. There are two components of the load transferred by the bending stiffener to the bell mouth: a) shear or radial force (transverse to the axis of the bell mouth) and b) bending moment. It has already been observed in other studies that the bending moment is the preponderant component that structurally sacrifices the bell mouth. Based on this context, the stiffener with zero (or almost) bending moment called BSsim was developed. The concept is relatively simple and figure 1 below can be used to follow the explanation:

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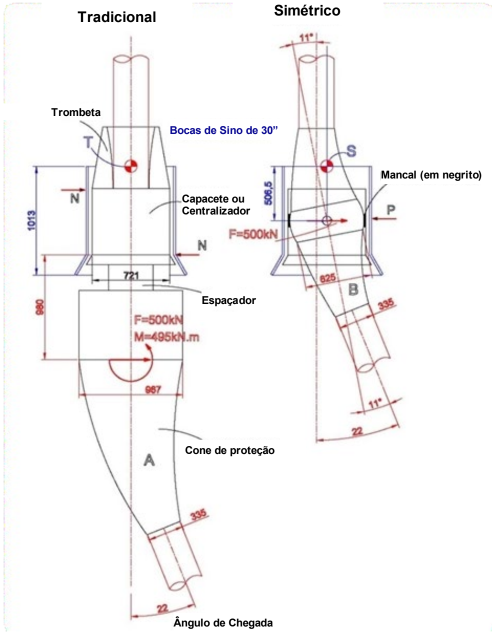
Figure 1 – Comparative diagram between a standard bending stiffener (left) with the BSsim bending stiffener concept (right).



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1) **Figure 1** above shows the diagram of two bending stiffeners: the one on the left represents a standard stiffener for a 9-inch riser with a 30-inch bell mouth (just shown); the one on the right shows the schematic of a zero bending moment stiffener, BSym, also for the same riser and the same 30-inch bell mouth. A summary study was designed to size the BSsim-concept so that both had the same performance under the action of extreme loading.

2) The main datum for understanding the concept is the riser arrival angle, or top angle, with the riser subjected to extreme loading. The figure shows the arrival angle of 22 degrees, the maximum that the stiffener must support, thus, the sizing detail for this initial assessment.

3) The traditional stiffener is embedded in the bell mouth, while the BSsim is swiveled. If the single protection cone of the traditional stiffener is replaced by a double protection cone and swiveled in its symmetry, it can be seen that the same arrival angle of 22 degrees will be divided, along the double cone, by two angles or, in other words, each (partial) cone of protection must bend (support) only 11 degrees.

4) Sizing the protection cone to 11 degrees instead of 22 degrees leads to a smaller geometry, as can be seen in the figure on the right of figure 1. Therefore, the BSsim concept allows the stiffener to be smaller than the traditional one and, since it is swiveled, it does not transfer the bending moment to the bell mouth, ensuring that the objective of reducing load is achieved.

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1.2 Geometry

Figure 2 shows a longitudinal section of the geometric model of the BSSim stiffener initially proposed by PETROBRAS. Its components are indicated in this figure, while Figure 3 presents them separately.

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Figure 2 – Longitudinal section of the geometric model of the BSSim stiffener and indication of its components.

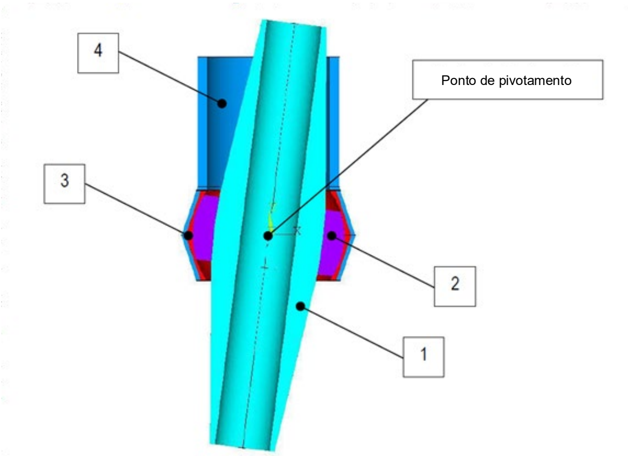

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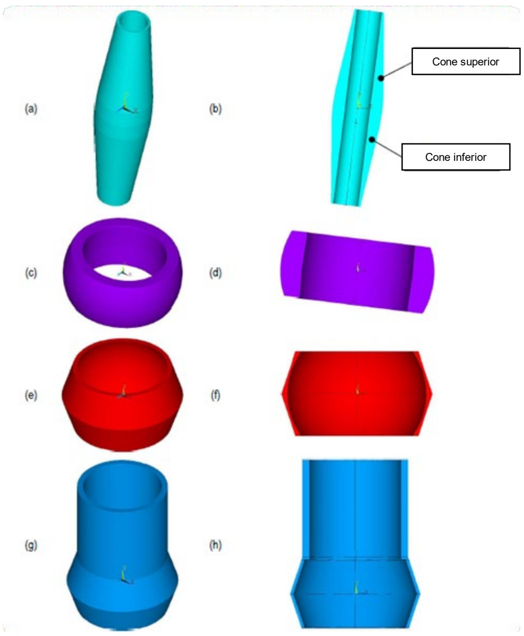
Figure 3 – BSSim components: (a,b) bending stiffener (double cone); (c,d) swivel; (e,f) bushing; (g,h) cap.



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1.2.1 As shown in **Figure 2**, the stiffener consists of four components:

1. Flexible pipe or double cone bending stiffener (Figure 3(a,b): single piece composed of three frustum-conical regions. Two of these regions have a prominent conicity (upper and lower cones), while the central region, connected to the swivel, has a small conicity.

2. Swivel: element connected to the double cone that allows it to rotate in relation to the fixed elements of the BSSim, that is, the bushing and the bell mouth.

3. Bushing: component that aims to minimize friction between the bell mouth and the swivel.

4. Cap: component that transfers the loads from the set formed by the swivel and the double cone to the support structure, in addition to confining and, consequently, limiting the rotation of the double cone.

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1.3 Materials studied

Sliding wear tests were performed between pairs of materials with potential for application in symmetrical articulated stiffeners with the aim of evaluating the effects of contact pressure on the wear rate and friction coefficient. Additionally, the respective degradation mechanisms of the materials of each pair were evaluated.

Three tribological pairs with high PV (contact pressure vs. sliding speed) were selected to have their behavior evaluated at different pressure levels, two pairs of materials from DUPONT® and one from RK. Samples from supplier DUPONT® were tested in polymer x polymer and polymer x metal configurations. The RK’s sample was tested only in the polymer x metal configuration. The sliding speed, as well as the water temperature, were kept constant in all tests. Figure 4 shows the idealized configuration for the tests.

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Figure 4 –Tribometer used in sliding wear tests.

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1.3.1 The pairs studied were as follows: polymer/polymer (DUPONT® versus DUPONT®), polymer/metal (D-GRLIDE® versus stainless steel) and polymer/metal (DUPONT® versus stainless steel). For execution, pressures and sliding speeds were selected based on field results.

Through the study of a real loading history (FPSO Capixaba), force levels were defined, generating possible test configurations for each pair of materials. Furthermore, the number of cycles at each level was also determined. Figure 5 shows a summary of the distribution of possible loads to be applied to the tests.

Figure 5 – Distribution of loading events.

Establish loading limits per block.					
Option adopting maximum cutting force		349.5			0
		Block 1	Block 2	Block 3	RO
Distribution of loads from the FPSO CAPIXABA case	kN	350	**100**	**80**	**45**
Route according to the loading block	m	15,686	22,424	312,742	148,515
Route according to the loading block	**km**	**16**	**22**	**313**	149
Percentage Path	**%**	**4.5**	**6.4**	**89.1**	29.7

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1.3.2 After analysis and some calculations, the two main levels to be studied were defined. One that reflects the loading condition analogous to 80 kN at the contact, which is understood to be the loading range where the equipment will operate for most of its useful life, and another that reflects the maximum load of 350 kN at the contact, which would be the extreme load applied to the system in a critical event.

As a definition of the other parameters, the final test configuration follows:

- Phase A: 400,000 cycles with a load of 4.8 tf on the equipment (ref. 0.75 MPa) and a speed of 7.5 mm/s, and in this case the oscillation frequency is approximately 0.25 Hz;
- Phase B: 100,000 cycles with a load of 21.1 tf on the equipment (ref. 3.25 MPa) and a speed of 5 mm/s, and in this case the oscillation frequency is approximately 0.17 Hz.

With this accelerated tribological process under test, the risk of overheating of the polymeric samples and consequent inadequate increase in the wear rate that we intended to investigate was identified. Therefore, a separation of approximately 10 seconds was defined every 20 cycles in all stages to allow an efficient heat exchange between the sample and the water, leaving the temperature of the specimens at a level compatible with that expected in operation.

The tests were performed in the following sequence:

- Test 01 (Pair 01): DUPONT® samples (Polymer x polymer): The materials of the DUPONT® samples are both made of Teflon®, with the swivel being made of Teflon® PTFE 2824 A and the bushing Teflon® PTFE 6507 A, respectively;
- Test 02 (Pair 02): RK samples (Polymer x metal): The second pair for testing was composed of stainless-steel swivel samples (AISI 304), sliding against D-Glide®;
- Test 03 (Pair 03): DUPONT® samples (Polymer x metal): For Test 03, AISI 304 stainless steel plain bearings and Teflon® bushings from DUPONT® were used, with the material of the Teflon® bushing being PTFE 6507 A, similar to Test 01.

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1.3.3 The results obtained allowed us to conclude that:

a. The pairs involving Teflon® samples showed a friction coefficient less than half the friction coefficient observed in the pair with D-GLIDE®. In pair 01, the friction coefficient was equal to 0.162 and 0.124 for Phases "A" and "B", respectively; pair 02 presented the highest friction coefficient among the materials tested, being equal to 0.308 in Phase "A" and equal to 0.292 in Phase "B"; pair 03 showed the lowest friction coefficient among the materials tested, being 0.123 and 0.100 for Phases "A" and "B", respectively;

b. The polymer/polymer pair (Test 01) showed the lowest wear rate for the bushing. However, the swivel experienced considerable wear, greater than that observed in metal swivels, especially for high contact pressures;

c. In Test 01 (Phase "A" and "B"), the predominant wear mechanism was adhesion with the presence of some micro-scratches. However, the kinematic characteristic of the test and the chemical affinity between swivel and bushing favored the adhered material to migrate between swivel and bushing, maintaining an interfacial film in contact;

d. The polymer versus metal pair in Test 02 (D-Glide® vs. stainless steel) had contact problems on the left side, which resulted in non-uniform wear on the bushing and swivel. This problem was not eliminated in its supposed origins and led to large vibrations in Phase "B," a fact that prevented the use of this result;

e. The wear mechanism in pair 02 was predominantly represented by contact fatigue, where portions of material are torn off by the propagation of fatigue cracks, which migrate to other regions of the contact. The intense deformation of these particles favored the formation of new cracks and repeated material detachment;

f. Although the D-GLIDE® bushing is more aggressive to the metal swivel, scratching it and eliminating the original roughness of the sample, the wear rates observed in the metal swivel are small compared to those of the polymeric swivel in Test 01;

g. Test 03 (DUPONT® vs. stainless steel) showed the lowest friction coefficient among the materials tested. It is worth mentioning that, in Phase "A," the bushing wear rates, considering the standard deviations, are close to those observed in Phase "A" of Test 01, however, with very low wear on the metal swivel;

h. A large difference was observed between the wear of the polymeric bushing on the left and right sides in Test 03, especially in Phase "B". This difference was associated with a difference in the direction of the finish applied to the metal hinges, although the surface finish obtained was similar;

i. The predominant wear mechanism for pair 03 was contact fatigue, combined with micro-scratching. It was observed that in this case, the existing fibers in the bushings also suffer from the abrasion of the swivel.

Legal Notice

The issuance of this RFI does not constitute a commitment to issue a request for bids/proposals, award a contract, or pay any costs incurred in preparing a response to this RFI.
PETROBRAS requires all responding suppliers refrain from providing any actual quotes or bids in response to this RFI.
This RFI is confidential and proprietary to **PETROBRAS**. Suppliers agree that they will not duplicate, distribute, or otherwise disseminate or make available this document or the information contained therein without the express written consent of **PETROBRAS**.
Suppliers must not include or reference this RFI in any advertising without the prior written approval of **PETROBRAS**, which, if granted, must be granted by PROCUREMENT.
Any information received in response to this RFI will be treated as confidential and will assist **PETROBRAS** in its decisions and the improvement of its processes.
Submitting a response to this RFI does not in any way guarantee that a vendor will be selected for any subsequent RFP, nor does it preclude any vendor from responding to future procurement opportunities.

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References

- Law 13,243/2016
  http://www.planalto.gov.br/ccivil_03/_Ato2015-2018/2016/Lei/L13243.htm
- Section V of Decree 9,283/2018
  http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2018/decreto/d9283.htm#art27
- Complementary Law 182/2021
  https://in.gov.br/en/web/dou/-/lei-complementar-n-182-de-1-de-junho-de-2021-323558527
- Petrobras: Connections for Innovation
  https://tecnologia.petrobras.com.br/

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Note

Please complete and submit this RFI by **January 19, 2024**.

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Consent Form

This document aims to record the free, informed, and unequivocal expression by which the data subject agrees to the processing of their personal data for specific purposes, in accordance with the Brazilian General Data Protection Law (13,709/18 - LGPD).

By expressing acceptance of this term, the data subject consents and agrees that Petróleo Brasileiro S.A - PETROBRAS, CNPJ 33.000.167/0001-01, with headquarters at Avenida República do Chile, 65, Rio de Janeiro, RJ, Brazil, hereinafter referred to as Controller, processes your personal data for specific purposes, in the manner and under the conditions described below.

By filling out this form, you are aware that Petróleo Brasileiro S.A - PETROBRAS, CNPJ nº33.000.167/0001-01, will use your personal data in accordance with the Brazilian General Data Protection Law (13.709/18 - LGPD), to send Invitations (and their feedback forms) to RFI-related events on screen, as well as making contacts related to this program.
*

◯ I accept

Questions

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Does the supplier have any development of a new type of stiffener that reduces bell mouth loads, similar to BSSim? *

If so, explain its solution, also stating whether it is commercial, prototype or just a concept.

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Would the supplier be willing to present a proposal for the development of a swiveled symmetric bending stiffener, in partnership with PETROBRAS? *