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|---|---|---|---|
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| | AREA: OFFSHORE BASINS - BRAZIL | | |
| SUB/ES | TITLE: RISER CONFIGURATIONS FOR INTERFERENCE ANALYSIS | | INTERNO |
| | | | ES/PSUB |

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| 0 | ORIGINAL ISSUE |

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| APPROVAL | Gustavo Adolfo | | | | | | |

## INDEX

## 1- OBJECTIVE

The objective of this document is to inform the reference riser configurations for the gathering system of typical scenarios for umbilical qualification. This information shall be used as input for the design of staggered riser configurations that ensure crossings at different vertical positions, avoiding contact between adjacent risers. Thus, SUPPLIERS will be able to assess similar conditions that may be encountered in a specific project demand during the qualification programs.

Due to the comprehensive scenario, the structures presented in this report are preliminary and may be modified within specific projects. However, the reference scenarios will provide greater possibilities of reaching feasibility within the projected evaluations. Any results from interference analyses performed with these configurations are preliminary and shall be revised within specific projects evaluation.

## 2- REFERENCES

[1] I-ET-3000.00-1500-29B-PAZ-001 Rev D – TECHINICAL SPECIFICATION FOR SUBSEA UMBILICAL SYSTEMS

[2] I-ET-3010.00-1519-274-PPC-001 REV 0 – RISER INTERFERENCE ANALYSIS

[3] DE-3913.00-1500-942-PMU-002_RX – ARRANJO SUBMARINO DA P-53 OPÇÃO MISTA (DUTO FLEXÍVEL + RÌGIDO)

[4] DE-3558.00-1500-942-PMU-008_RJ – ARRANJO SUBMARINO DE INTERLIGAÇÃO DO CAMPO DE TARTARUGA VERDE E MESTIÇA

[5] DE-3A26.02-1500-942-PMU-003_RK – ARRANJO SUBMARINO DE INTERLIGAÇÃO DO CAMPO DE LULA SUL (FPSO P-66)

## 3- RISER CONFIGURATIONS AND INTERFERENCE RESTRICTIONS

In this document, in addition to establishing a generic requirement for the assessment of umbilical interference with mooring lines, three general reference scenarios, as described below, are provided.

**Table 1 – Scenarios Description**

| Scenario | Adjacent Risers | | Correlation with I-ET-3000.00-1500-29B-PAZ-010 [10] |
|---|---|---|---|
| | Configuration | Pipe | |
| A | Lazy wave and Free Hanging | Flexibles | Scenario II |
| B | Lazy wave and Free Hanging | Rigids and Flexibles | Scenario II |
| C | Free hanging | Flexibles | Scenario I |
| Mooring Lines Interference Assessment | Lazy wave and Free Hanging | Flexibles | Scenario I and II |

### 3.1 – Internal Fluid Variation

Internal fluid ranges were defined according to the application scenarios and reference technical specification [1]. Table 2 sets the maximum and minimum fluid conditions during normal and eventual operations.

**Table 2 – Fluid Parameters for Interference Analysis**

| Riser Function | Normal Operation | | | Eventual Operation | |
|---|---|---|---|---|---|
| | $\gamma_{min}$ (tf/m³) | $\gamma_{mp}$ (tf/m³) | $\gamma_{max}$ (tf/m³) | $\gamma_{min}$ (tf/m³) | $\gamma_{max}$ (tf/m³) |
| 6in Production | 0.250 | 0.550 | 0.900 | 0.000 | 1.140 |
| 8in Production | 0.250 | 0.550 | 1.025 | 0.000 | 1.140 |
| Water Injection | 0.820 | 1.025 | 1.025 | 0.000 | N/A |
| Gas Injection | 0.000 | 0.600 | 0.750 (*)<br>1.025 (**) | N/A | 1.025 |
| Gas Lift / Service | 0.000 | 0.400 | 0.865 | N/A | 1.025 |
| Gas Export | 0.120 | 0.250 | 0.350 | 0.000 | 1.025 |

*(*) Only applicable for scenario A*
*(**)Only applicable for scenario B*

It should be noted that the most probable value of fluid density ($\gamma_{mp}$) is only a reference for the riser configuration adjustment. The global configuration parameters given below consider the FPSO at nominal position and mean draft, with buoyance modules at end of life.

The configurations shown here consider the water depths (WD) informed in each section, which can undergo slight changes within specific projects. In such

cases, if the WD at the TDP is different from that indicated in this report, it shall be applied a correction proportional to the WD variation on the riser section lengths, Riser-Flow connection distance and horizontal projection while maintaining, as much as possible, the specified top angle. In this way, it is possible to obtain similar configurations with minor adjustments.

### 3.2 – Riser Configurations of Scenario A

The configurations in this section refer to a scenario where it is possible to have flexible lazy wave risers, steel tubing umbilicals and thermoplastic umbilicals in the same project. It shall be considered that both umbilical structures (steel tubing and thermoplastics) can be used in any umbilical support position. Therefore, any new umbilical cross section shall be designed considering the restrictions imposed by these configurations and the interference criteria [2].

The Lula Sul field layout, with WD of 2160 m, shall be considered as reference for this scenario [5].

The 6in Gas Injection riser configuration and global parameters are presented in Figure 1 and Table 3.

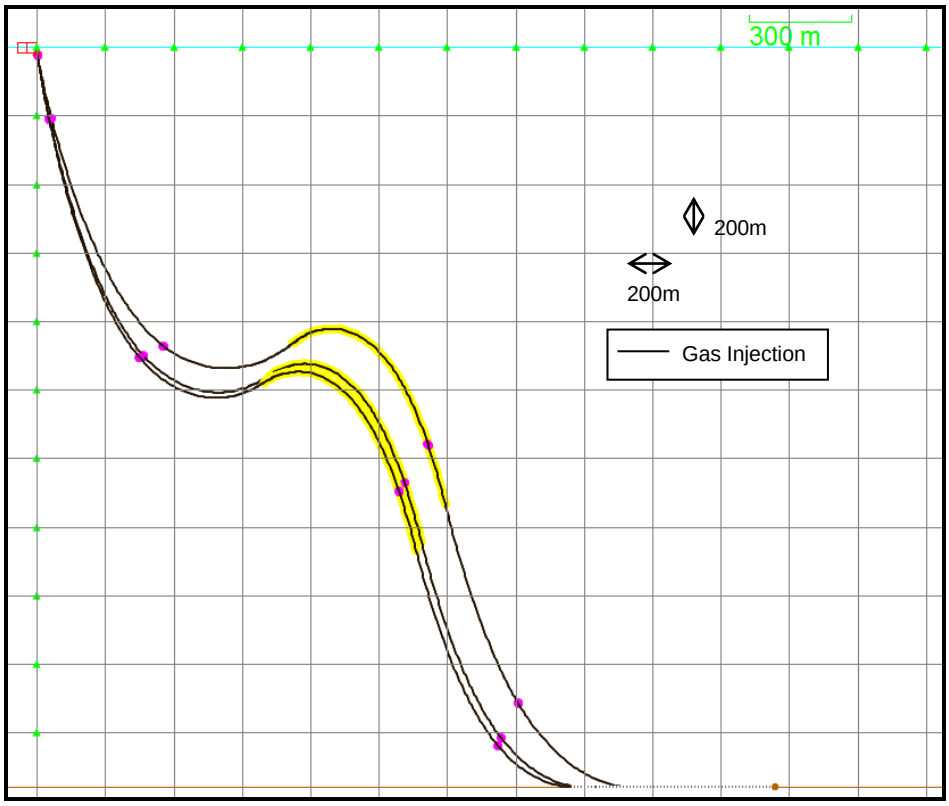



**Figure 1 – 6in Gas Injection Configuration**

**Table 3 – 6in Gas Injection Global Parameters**

| Riser Global Parameters | Top Angle (deg) | HOG distance from seabed (m) | SAG distance from seabed (m) | Horizontal distance to TDP (m) |
|---|---|---|---|---|
| γmax | 9.11 | 1214 | 1138 | 1569 |
| γmp | 9.42 | 1236 | 1154 | 1609 |
| γmin | 10.88 | 1334 | 1223 | 1749 |

The 6in Oil Production risers have sag/hog positions immediately below the gas injection line, as shown in Figure 2 and Table 4.

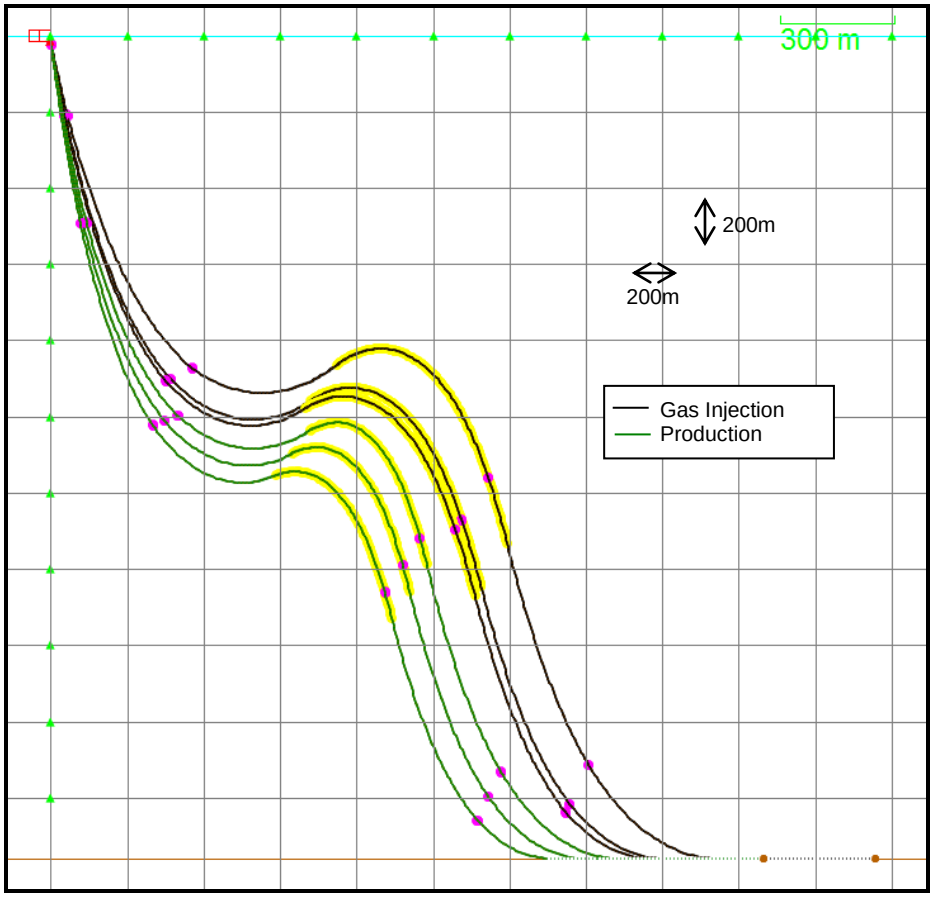



**Figure 2 – Inclusion of 6in Oil Production Configuration**

**Table 4 – 6in Oil Production Global Parameters**

| Riser Global Parameters | Top Angle (deg) | HOG distance from seabed (m) | SAG distance from seabed (m) | Horizontal distance to TDP (m) |
|---|---|---|---|---|
| γmax | 7.11 | 1015 | 987 | 1305 |
| γmp | 7.73 | 1081 | 1030 | 1395 |
| γmin | 8.42 | 1146 | 1077 | 1484 |

The 8in Water Injection risers and Steel Tubing Umbilicals shall be defined within the configurations described below.

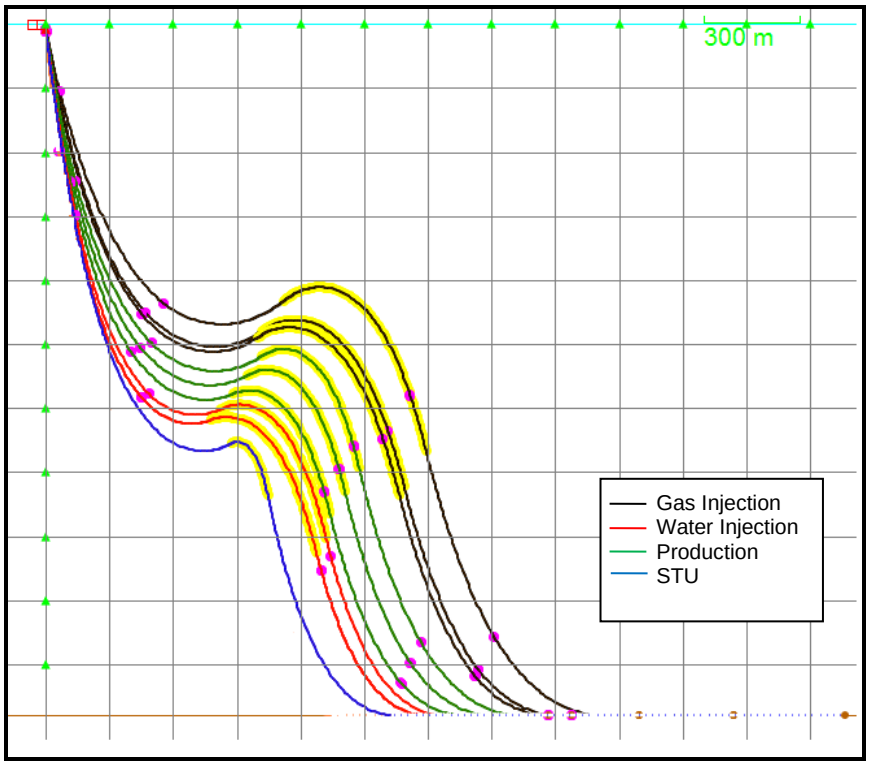



**Figure 3 – Inclusion of 8in Water Injection and STU Configurations**

**Table 5 – 8in Water Injection Global Parameters**

| Riser Global Parameters (*) | Top Angle (deg) | SAG distance from seabed (m) | HOG distance from seabed (m) | Horizontal distance to TDP (m) |
|---|---|---|---|---|
| $\gamma_{max}$ | 6.21 | 893 | 904 | 1159 |
| $\gamma_{mp}$ | 6.21 | 893 | 904 | 1159 |
| $\gamma_{min}$ | 6.57 | 919 | 943 | 1210 |

**Table 6 – Steel Tubing Umbilical Global Parameters**

| Riser Global Parameters | Top Angle (deg) | HOG distance from seabed (m) | SAG distance from seabed (m) | Horizontal distance to TDP (m) |
|---|---|---|---|---|
| $\gamma_{mp}$ | 6.50 | 853 | 826 | 1091 |

Free hanging (FH) catenary configurations do not present relevant geometric differences upon internal fluid variation. Therefore, to create a configuration gap with nearby lazy waves, a reduction on the top angle of free hanging configurations is necessary. Hence, the top angle of 5 degrees shall be considered as the base case

for the free hanging configurations (Service/Gas Lift, Water Injection 6 in, Thermoplastic Umbilicals).

In case of any modifications on the proposed configurations, proper justification shall be presented. Additionally, it must be shown that any impact regarding interference with neighboring risers is irrelevant.

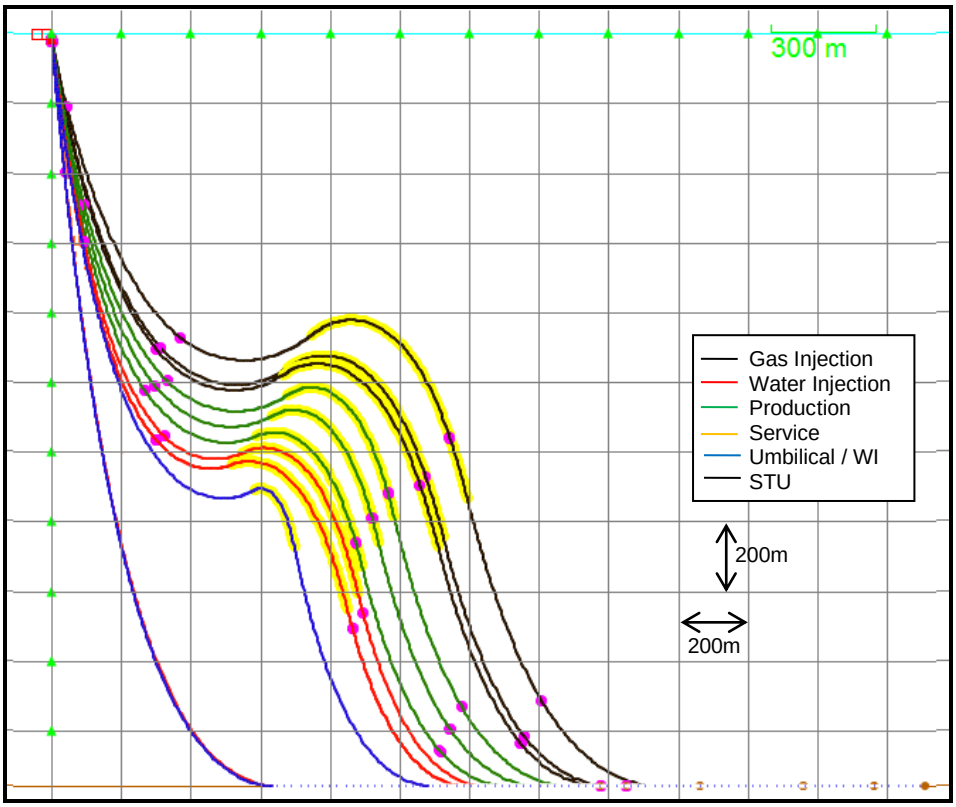



**Figure 4 – Inclusion of 6 in Water Injection, Gas lift and Umbilical in FH Configurations**

**Table 7 – Free Hanging Catenary Risers Global Parameters**

| Riser Global Parameters | Top Angle (deg) | HOG distance from seabed (m) | SAG distance from seabed (m) | Horizontal distance to TDP (m) |
|---|---|---|---|---|
| $\gamma_{mp}$ | 5 | N/A | N/A | 645 |

### 3.3 – Riser Configurations of Scenario B

The conceptual SLWR field layout [4], with WD of 1980 m, shall be considered as reference for this scenario.

Free hanging catenary risers shall have 5 degrees of top angle, resulting in the characteristics described in Table 9.

**Table 8 – Global Parameters for Free Hanging Catenary Risers**

| Riser Global Parameters | Top Angle (deg) | HOG distance from seabed (m) | SAG distance from seabed (m) | Horizontal distance to TDP (m) |
|---|---|---|---|---|
| $\gamma_{mp}$ | 5 | N/A | N/A | 573 |

Figure 5 and Table 10 below present the SLWR configuration for 6.5in WAG Injection risers.

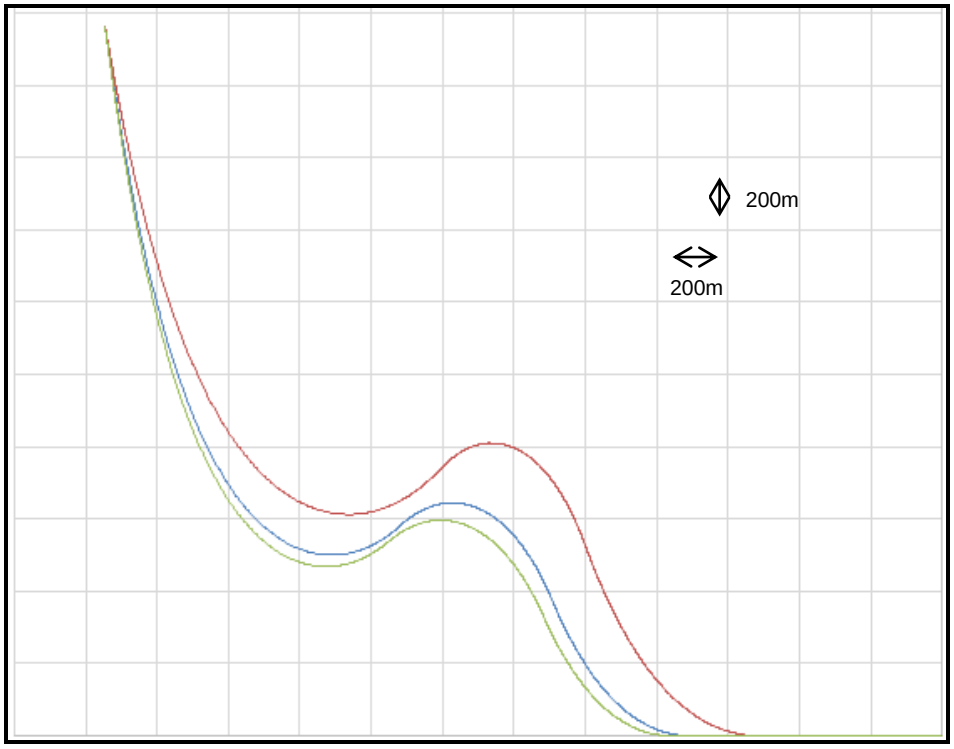



**Figure 5 – 6.5in WAG Injection SLWR Configuration**

**Table 9 – 6.5 in WAG Injection SLWR Global Parameters**

| Riser Global Parameters | Top Angle (deg) | HOG distance from seabed (m) | SAG distance from seabed (m) | Horizontal distance to TDP (m) |
|---|---|---|---|---|
| $\gamma_{max}$ | 7.6 | 598 | 471 | 1583 |
| $\gamma_{mp}$ | 8.0 | 646 | 503 | 1637 |
| $\gamma_{min}$ | 9.7 | 811 | 615 | 1828 |

Figure 6 and Table 11 present the SLWR configuration for 8in Oil Production risers.

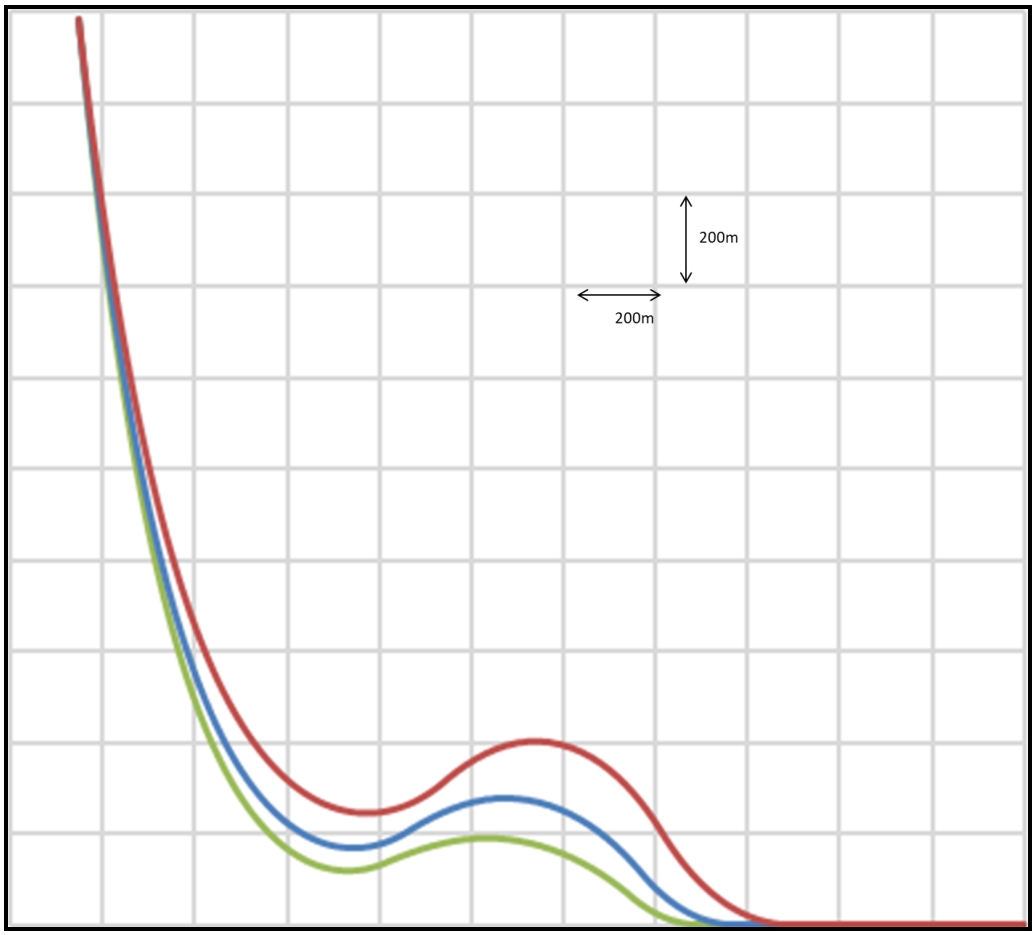



**Figure 6 – 8in Oil Production SLWR Configuration**

**Table 10 – 8 in Production SLWR Global Parameters**

| Riser Global Parameters | Top Angle (deg) | SAG distance from seabed (m) | HOG distance from seabed (m) | Horizontal distance to TDP (m) |
|---|---|---|---|---|
| $\gamma_{max}$ | 5.3 | 118 | 190 | 1348 |
| $\gamma_{mp}$ | 5.6 | 168 | 277 | 1424 |
| $\gamma_{min}$ | 6.3 | 245 | 402 | 1544 |

### 3.4 – Riser Configurations of Scenario C

The configurations in this section refer to a scenario where it is possible to have flexible lazy wave risers, steel tubing umbilicals and thermoplastic umbilicals in the same project. It shall be considered that both umbilical structures (steel tubing and thermoplastics) can be used in any umbilical support position. Therefore, any new umbilical cross section shall be designed considering the restrictions imposed by these configurations and the interference criteria [2].

The field layout of Marlim Leste (P-53), with WD of 1085 m, shall be considered as a reference of this scenario [3].

The free hanging catenary risers can have 7 or 9 degrees of top angle, resulting in the characteristics presented in Table 13.

**Table 11 – Free Hanging Catenary Risers Global Parameters**

| Riser Global Parameters | Top Angle (deg) | HOG distance from seabed (m) | SAG distance from seabed (m) | Horizontal distance to TDP (m) |
|---|---|---|---|---|
| $\gamma_{mp}$ | 7 | N/A | N/A | 434 |
| $\gamma_{mp}$ | 9 | N/A | N/A | 527 |

In this scenario, the STU configuration is described below.

**Table 12 – STU Global Parameters**

| Riser Global Parameters | Top Angle (deg) | HOG distance from seabed (m) | SAG distance from seabed (m) | Horizontal distance to TDP (m) |
|---|---|---|---|---|
| $\gamma_{mp}$ | 9 | 100 | 78 | 772 |

### 3.5 – Mooring lines vs. Umbilical Interference Criteria

On a pre-salt and pos-salt spread moored FPSO, the umbilicals shall respect the criteria defined regarding clashing with mooring lines and crossing below mooring lines under 98% non-exceedance current [2].

The field layout of “Lula Sul” and “Tartaruga Verde e Mestiça” [6,8] shall be considered as a reference to check mooring lines interference criteria.

Figure 8 illustrates the mooring line sectors (NE, SE, SW and NW) with adjacent riser positions. Every pair mooring line x riser needs to be verified.

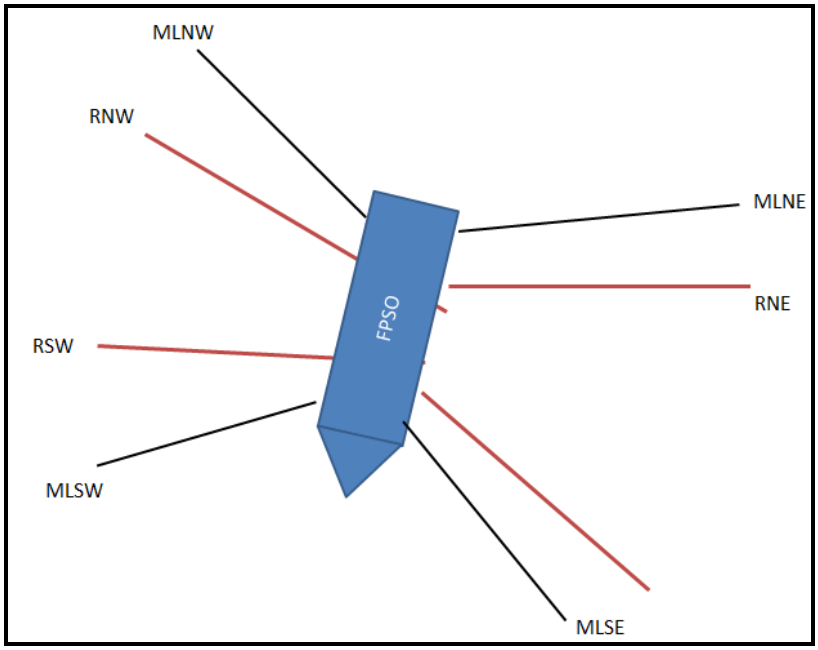



**Figure 7– Mooring line sectors and adjacent riser positions.**

Figure 9 illustrates the FPSO local conventions.

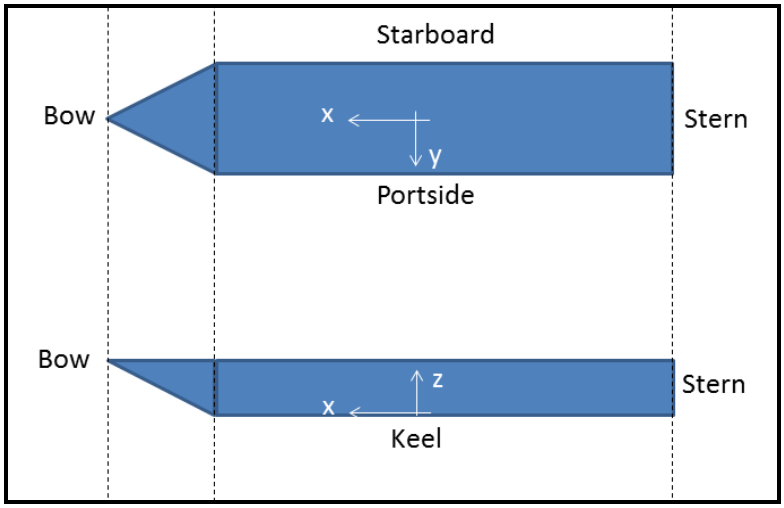



**Figura 8– FPSO local Conventions.**

The table below indicates the interference criteria and mooring line reference positions.

**Table 13- Interference Criteria and Mooring Line Reference Position**

| Cluster | Longitudinal Distance between Riser Slot and Fairlead (m) | Azimuth Difference between Riser x Mooring Line (deg) | Fairlead Local Positons (X,Y,Z) (m) | Mooring Line Azimuths |
|---|---|---|---|---|
| SE | 35 | 3 | 115, 30, 2 | As per Field Layout |
| SW | 65 | 10 | 115, -30, 2 | As per field Layout |
| NE | 35 | 3 | -115, 30, 2 | As per Field Layout |
| NW | 65 | 7 | -115, -30, 2 | As per Field Layout |

Mooring lines shall be modelled as segments with the properties indicated in the Table 16.

**Table 14 - Material properties of mooring line segments**

| Segment | Nominal Diameter | MBS (*) | EA (**) | Weigth$_{air}$ (***) | Weigth$_{fac}$ (****) | Cd | Cm |
|---|---|---|---|---|---|---|---|
| Bottom chain | 120 mm | 13573 kN | 1100 MN | 2,853 kN/m | 0,870 | 2.2 | 2 |
| Poliester Cable | 208 mm | 12300 kN | 184 MN | 0,274 kN/m | 0,263 | 0.7 | 2 |
| Top Chain | 120mm | 13573 kN | 1100 MN | 2,853 kN/m | 0,870 | 2.2 | 2 |

(*) MBS: Minimum Break Strength.

(**) EA: Constant value in the table for the polyester cables is the quasi static value. The dynamic value is obtained by the expression EA = 0.25*Tm+19, Where T is the mean of the tension in percentage of the MBS and the EA is obtained in MBS, that is, the result must be multiplied by the MBS of the cable.

(***) Weigth in air

(****)Weight ratio in water relative to weight in air.

The table below indicates the mooring lines segment length.

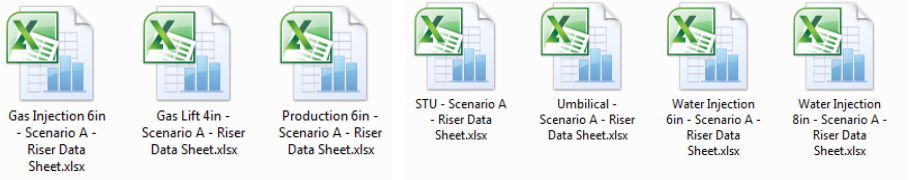
**Table 15- Typical mooring line segments length**

| Segment | Length |
|---|---|
| Top Chain | 150m |
| Poliester Cable | Variable |
| Bottom Chain | 350m |

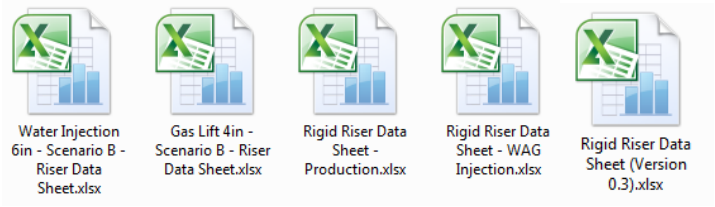
The length of the variable section shall be calculated by considering an anchoring radius equal to 1,00*WD (Water Depth), adjusting the anchor line pre-tension (top) to the value of 1750kN (FPSO at intermediate draft – 16m).

## 4- ATTACHMENTS

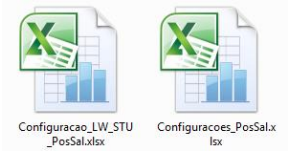
**Scenario A:**



## Scenario B:




## Scenario C:




## Reference Field Layouts: