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## Albacora Leste Field Development—FPSO P-50 Mooring System Concept and Installation

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### ABSTRACT

The mooring system designed for P-50 is an 18-line, partially compliant spread mooring system, with 10 lines in the bow and 8 lines in the stern. Polyester ropes and steel chain in a semi-taut configuration compose all mooring lines. The polyester ropes were rated for 1400 tons of Minimum Breaking Load, leading this project to present the heaviest synthetic mooring system ever designed for any kind of floating production Unit.

For the fixed points of the mooring system, instead of using Vertically Loaded Anchors (VLAs) employed in previous projects, it was decided to use free fall piles, also known as torpedo piles, to anchor the lines to the soil. Such piles had already been used in the Campos Basin to anchor flexible lines at the subsea, as well as to moor Mobile Drilling Rigs. In these installations and in the real scale driving tests of P-50 piles that were performed in 2002, it was possible to confirm that free fall piles were much easier and faster to be installed than similar solutions such as VLAs and Suction Piles.

These tests also showed the importance to measure and control the tilt angle of the torpedo during installation, since analytical calculations had earlier shown that the pile ultimate holding capacity could be strongly reduced if the pile was installed in an inclined position inside the soil.

So, after these tests, some technical modifications were made in the installation accessories, in order to make the piles installation easier:

- Release link: Instead of releasing the torpedo installation line from the surface, a submerged released link was used reducing the drag effect in the lines and increasing the pile driving velocity;
- Monitoring bottle: Some improvements were adopted in the removable bottle where the

instruments used to record the driving parameters (penetration, inclination and velocity) were enclosed.

The main objective of this paper is to describe how P-50 mooring system installation was planned and executed.

### INTRODUCTION

Since the end of the 90's, free fall piles, also known as "torpedoes", have been used offshore Brazil. Initially, torpedoes were used to moor flexible risers to the sea-bottom and later, to moor semi-submersible drilling rigs. In April 2001, a design certified by the Classification Society Bureau Veritas, called T-43 design (a torpedo pile weighing 43 tons) was developed for this before mentioned application. In the beginning of 2002, the first T-43 torpedoes were successfully used to moor a deepwater drilling rig and in the next 3 years, more than 50 T-43 torpedoes had already been installed in the Campos Basin.

The T-43 torpedo was also used to moor the FSO Avaré, a former 30,000 dwt tanker that was installed in the Santos Basin (offshore Brazil). The Avaré mooring system was certified by Classification Society American Bureau of Shipping (ABS) in 2004.

Even before the installation of the Avaré, the good results of the installation of drilling rigs employing T-43 torpedoes showed that there was a large scenario for the application of torpedoes to moor Floating Production System in deep water fields under development in the Campos Basin.

The mooring analyses of the FPSO P-50 showed that the required anchor holding power would be very high (~1,000 tons) and the use of the DICAS (Differentiated Compliance Anchoring System) mooring system, with polyester ropes, would require the use of anchors with vertical holding capacity, such as VLAs (Vertical Loaded Anchors) or suction piles. Petrobras had in the past successfully used VLAs to moor semi-submersible Floating Production Units, such as P-27 [1], P-36 [2] and P-40 in the Campos Basin. However, for the holding capacity required to moor P-50 (a 270,000 dwt tanker), it would be necessary 3 or 4 Anchor Handling Vessels (AHV) with sufficient bollard pull in order to embed the anchors in the soil. Moreover, the previous experience with the P-43 installations showed