



PRE-INSTALLATION OF CONDUCTOR CASINGS USING A STANDALONE OFFSHORE CONSTRUCTION VESSEL

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Abstract

During last decade the concept of conductor casing pre-installation was introduced in the offshore oil and gas industry and proved to be an interesting choice for operators in order to save rig time during exploratory campaigns. Three projects were executed in Brazil summing 36 conductor casings with 36 and 48 inches outside diameter.

The methodology discussed in this paper for conductor casing deployment includes an offshore construction vessel (OCV), an oceangoing barge with tug, a subsea hammer and a work-class ROV. These resources are able to install each conductor casing to the desired stick-up with fine accuracy. Although many benefits exist, the lead-time for full mobilization and the welding of the conductor casing is the downside with this pre-installation method, additionally multiple vessels in the field always require special attention with regards to safety.

This paper is intended to present an improvement from the previous pre-installation methodology. Conductor casing and hammer will be loaded on a single OCV, so there is no need for the oceangoing barge. Standard conductor casings with threaded connectors are horizontally assembled onshore on the mobilization quayside.

A conductor casing of 60 meters length becomes a challenge to be carried on the back deck of a regular OCV. A tailor made structure called Conductor Overboarding Platform (COP) was engineered to support up to 5 conductor casings with 36 inches diameter or similar configurations. Because the structure is modular it can be mobilized at any port on a light OCVs.

Simplicity of the presented incremental technology can support deepwater exploration and production activities in Brazil or worldwide saving considerable rig time and all associated costs. Risks are also reduced and even a last-minute decision to pre-install the conductor casing is feasible, since all consumables are off-the-shelf and the installation equipment is designed to be flexible and mobile.

1. Introduction

The methodology presented in this paper, is a new solution based on the InterMoor expertise from previous conductor casing pre-installation campaigns. Three projects were executed in Brazil totaling 36 conductor casings, using an offshore construction vessel (OCV) with a subsea hammer and a work-class ROV and an oceangoing barge with tug,. With the new methodology all parts are loaded on a single OCV.

The COP is a tailor made structure engineered to support up to 5 conductor casings of 36 inches diameter or similar configurations. The COP is equipped with its own pipe handling system, which also performs the conductor overboarding.

Once the conductor casing is launched horizontally in free fall to the water, the vessel's work wire receives the load while the conductor is uprighted through a pendulum movement. The load is transferred from the winch to the vessel's active heave compensated (AHC) crane and then lowered to the seabed.

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Positioning and soil penetration is controlled from the OCV using the AHC crane and the ROV. As soon as the conductor casing has penetrated the seabed by its self-weight, the subsea hydraulic hammer is used to drive the conductor to the desired stick-up. The overboarding and the penetration methodology is detailed in this paper.

Engineering behind the operational methodology is based on structural analysis, dynamics, vessel stability, machinery and logistics. A numerical dynamics simulation was carefully modeled in order to calculate worst load cases during all installation steps, including the conductor splash zone passage.

Worst dynamic cases are the challenge for the engineers. Due to operational reasons the COP framework has to elevate all conductors above the main deck level and also must create a stern overhang support due to the conductor's length. Finite Element Analysis (FEA) was used to model all load cases, which is briefly explained in the paper.

Savings from pre-installing conductor casings are particularly suited for scenarios with deepwater fields and/or installation of multiple conductor casings for full field drilling programs:

- Pre-installation is executed off the rig's critical path and based on OCV's availability window
- Driven conductors provide higher holding capacity than jetted conductors
- Subsequent drilling operations can be performed just after the conductor casing is driven
- Accurate positioning of the well location prior to the drill rig arrival
- Accurate stick-up provided by the hammer
- Conductor inclination less than 1 degree

The COP, considered a second generation of conductor casing pre-installation, adds benefits to the previous list and the paper shows solid arguments for the following improvements:

- Increased safety due to a single vessel offshore installation instead of multiple vessels
- Quick and easy mobilization instead of a long lead-time for equipments and vessels
- Off-the-shelf casing joints with threaded connectors instead of welded conductors
- Contractual negotiations and risk assessment enhanced as the methodology allows contingency installation (traditional rig installation)
- Cost reduction and lower break-even point in the number of wellheads to be installed when compared to the jetting methodology

2. Field proven concept

A patented concept by Wilde, Van Luipen and Zamboni (2005) to pre-install conductor casings was proved in the field in 2007. In order to save rig time, simpler resources like an Offshore Construction Vessel (OCV) and an oceangoing barge were able to pre-install the first string of casing of a well assisted by a work class ROV and a deepwater subsea hydraulic hammer.

Considering the Brazilian oil and gas scenario with deeper fields under development and scarce availability of rigs in the market, every saved day of such a valuable asset is important. Three projects were completed with success since the concept's development, totaling 36 conductor casings pre-installed (all with 36 or 42 inches outside diameter). So far, all projects pre-installed welded conductor casings up to 60 meters long (equivalent to 5 standard joints) and wall thickness up to 1.5 inches, weighing between 55 and 80 tons.

A short description for the pre-installation methodology is listed below for reader's reference before the introduction to the improvement herein disclosed, which is the main subject of this paper. A typical offshore campaign to pre-install conductors, including mobilization and demobilization, is comprised by following steps:

Pre-operation

1. Deepwater Subsea Hammer mobilization and commissioning on the OCV
2. Barge modification – install support beams, rails for handling system and crew accommodation on a flat barge
3. Barge load-out with conductor casings

Field preparation

4. OCV transits to installation field and configures the survey system
5. Barge (plus tug vessel) transits to installation field with all conductor casings onboard

Conductor deployment

6. OCV approaches the barge in the rendezvous zone
7. OCV's crew throws a messenger line to the barge's crew

8. OCV's work wire is connected to the conductor's head with a special lifting tool
9. The conductor is launched horizontally over the barge side using Shuttle System handling equipment
10. Conductor passes the splash zone and swings as a pendulum movement to the upright position hanging on the work wire.
11. OCV's deck crew transfers the load from the work wire to the Active Heave Compensated (AHV) crane
12. OCV's crane lowers the conductor casing through the water column
13. At the seabed the conductor penetrates by its self-weight
14. Depending on the soil data, penetration can be aided by suction technique
15. All conductor casings on the barge are deployed following steps 6 to 14
16. Barge is released to return to port

Conductor driving

17. Subsea Hammer is deployed and lowered to near the seabed
18. Subsea Hammer drives all conductor casings to the required stick-up with centimeters of precision
19. Subsea Hammer is recovered

Final delivery

20. As-built survey is performed to record final position and inclination of each conductor casing

Post-operation

21. OCV transits to the demobilization port
22. Subsea Hammer is demobilized
23. OCV is demobilized
24. Barge is demobilized

It is important to draw the attention to the ability of this methodology in terms of positioning. The survey system setup in the step 4 allowed the installation team to monitor and control the position and inclination of conductor hanging in the crane hook in real time from the OCV's control room. The positioning in the coordinate x-y reaches the precision of few centimeters, while inclination was set in less than 0.5 degree and the final stick-up was delivered within ± 10 centimeters tolerance.

A case study published by De Silvio, Pereira and Ruiz (2013) illustrates these and other advantages of the pre-installation method.

2.1. Known limitations on the concept

Despite the success of all 3 projects mentioned in the previous section, few limitations were learnt from them. The method still presents advantages to the field operator, even though eventual solutions would enable a broader use of this technology by the market. The feasibility of any project is mainly related to the number of conductors to be installed, a project to install 4 or 5 conductors is likely feasible, but pre-install 1 or 2 conductors is likely to be cost prohibitive. Below is listed such known limitations:

(i) Welded joints instead of threaded connectors impact directly the operator's supply chain; when the conductor casing is committed with the OCV and the barge methodology, in case of serious issue there is no allowance to the operator return to the rig's plan. Worst than that, such commitment should occur months ahead in order to qualify and execute the weld, which is not realistic in most of field development campaigns.

(ii) Barge modification is a direct cost to the project and must be split by all conductors pre-installed; in case of a single conductor casing, by instance, it turns economically unfeasible.

(iii) Hammer mobilization is another direct cost, which the higher contribution is the international freight and Brazilian importation taxes.

(iv) OCV and Barge approach in step (6) is an acceptable and manageable operation, but if avoided turns the operation much easier, quicker and safer.

Based on above lessons learned, a new concept was proposed and designed to the market. Barge was removed from the process, impacting directly in steps (2), (3) and (5) to (9) of the procedure presented in the previous section; also regular threaded connectors are used instead of welded joints. These modifications along the use of a single OCV will: (a) reduce costs, (b) allow a last minute decision by the operator, (c) turn the pre-installation of conductor casings as a routine operation – and not a special project – and (d) increase safety in the field.

3. Overview of Conductor Overboarding Platform

The concept herein presented was baptized as "Conductor Overboarding Platform", or simply COP. The philosophy behind the COP was to bring the barge conductor handling structures on the back deck of an Offshore

Construction Vessel (OCV). Previous concept worked very well and a strong requirement for the new concept was execute changes that were really necessary, keeping the essence of the pre-installation methodology.

In the effort to build the barge's structure over the vessel's deck few challenges raised up:

- A typical conductor casing is longer than a typical OCV back deck
- COP had to be simple and adjustable to different OCVs through a quick mobilization
- OCV's stability had to be maintained
- Operational weather limits had to be reasonable for Brazilian market

A structured project plan was created with the engineering team in order to design an innovative but simple equipment to tackle known limitations in the Section 2.1 and address above challenges.

First main change is the ability to use threaded connectors, which are assembled onshore by an alignment set of rollers and modified belt tong to ensure required torque. It takes away the limitation (i) in the Section 2.1 and allows the operator to pre-install the regular conductor casings already purchased for the drilling rig, for instance, few weeks before the rig arrival.

Other important changes were the transportation over an overhang structure and the pendulum behavior in the water. After this, as soon as the conductor is upright hanging by the work wire, the remaining installation is exactly the same as the initial concept in the Section 2.

4. Operational and survival weather criteria

Intended to be used in multiple fields and basins, the COP has to be suitable for harsh conditions. But to find acceptable weather criteria rather than over dimensioned numbers was important to provide a suitable solution to the offshore industry. Not only were the operational criteria defined, but survival criteria as well. The operational criteria were based on other limits in an OCV, like the crane and ROV limits, i.e., there is no reason to maintain the equipment operational when the crane had shutdown or the ROV is not able to dive.

On the other hand, while transporting long and heavy conductors it would be critical to keep the vessel in the field in case of poor weather conditions. Otherwise the vessel should look for sheltered water in case the weather forecast deteriorates, penalizing the operator with long transit times. Preliminary analysis showed wave height and wave period are main factors to the vessel's motion and loads in the COP structure.

Sea conditions in the Santos Basin are known as swell dominant, for this reason this area was the most important reference for the design engineers. Based on statistical analysis of the metocean data from Campos and Santos Basin, the Table 1 was created and used across the project life.

Table 1. Comparing approaches

Criteria	Operational	Survival
Wave significant height	2.5 m	4.0 m
Wave period	6 to 12 sec	6 to 12 sec
Wind speed	30 knots	-
	<u>Chance to not operate</u>	<u>Chance to leave the field</u>
Campos Basin	6.8%	0.4%
Santos Basin	11.7%	3.0%

Significant wave height was essential to find the COP's structure height, which will be explained in the next section. Any design based on vessel's motions in response of Table 1 weather conditions would be considered vessel-specific, which was not desired for the project. In order to design the equipment for any OCV, the structural integrity was calculated in DNV structural standards, to be detailed in following sections.

5. Suitable structure height

The height of COP's structure is important to keep the conductor casings away from the sea level. Conductor casings in Brazil are typically 60 meters long (when all connectors are made up), while OCV's main deck usually ranges between 35 and 45 meters. Clearly any attempt to load-out conductor casings directly on the deck will result in a hang over at the stern.

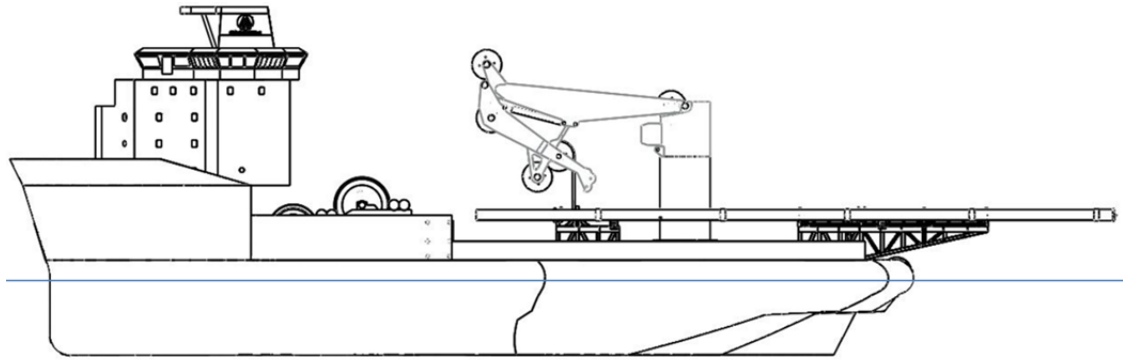


Figure 1. OCV with the COP.

A simple solution was to rise up the conductor casing up to a level in which, even with worst vessel movements, the casing would not touch the waves. An eventual touch could overload the structure, which was not acceptable to the project.

There is no deterministic solution to find this height, so four vessels were selected and their motions were simulated in an Orcasflex model for hours considering multiple weather cases based in the Table 1.

A statistical analysis showed the conductor casings should be transported at 4.5 meters above the deck.

6. Overhang support over the stern roller

Next issue due to the extra length of each casing was the supporting points on the conductor. Obviously damages on the conductor are not allowed and if a vertical support structure was designed on deck, the most aft supporting point would be located a fair distance from the center of gravity (CG).

A long overhang portion of the conductor would induce high stresses and high motions. The solution was to extend the COP's structure to some point in the conductor overhang part. A simple beam model provided the engineers with the optimum quantity of supports and locations. The final COP structure was designed with approximately 12 meters overhang from the stern roller.

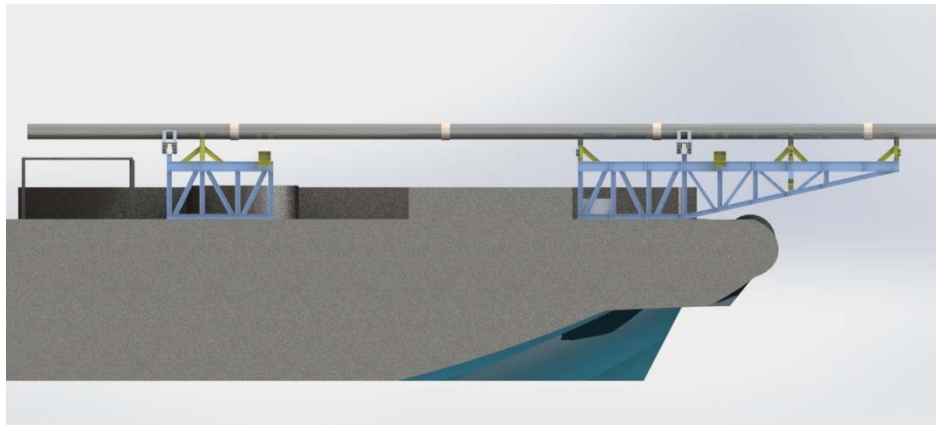


Figure 2. Section view of the COP on deck

The overhang structure was the driver of structural engineering and several revisions were required to find a lean and strong shape, which will be detailed in the next section.

7. Refining the COP structure shape

After main dimensions were found based on conductor's length and constrained by threaded connector's zones, a more detailed model was built using Finite Element Analysis (FEA) software. Multiple concepts were developed for comparison and an integrated group of engineers evaluated pros and cons of each one. Decision was made based in the fabrication process, operational aspects and Brazilian suppliers.

Some requirements for structure were:

- Stiff enough to avoid dynamic movements (bending) of the conductor
- Modular to be transported inside standard ISO containers
- Center of gravity balanced to ensure stability during assembly process onshore and lifting
- Easy mobilization to the vessel, i.e., simple seafastening
- Not vessel-specific and mirroring, i.e., fit to different vessel at port or starboard side

Initial models showed such a structure was feasible but with serious challenges to be solved. Two pieces were designed as shown in the figure 3, the forward structure is the simplest, while the aft part is a more complex truss which has approximately 12 meters behind the stern roller.

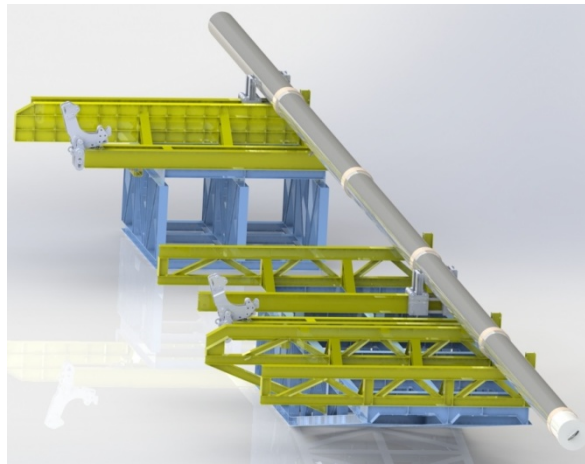


Figure 3. COP perspective view

When tons of pipes are carried and handled, safety is the main concern of all stakeholders. Conformity of engineering was bound by international standards according to the Table 2 in order to ensure structural integrity in operational and survival conditions.

Table 2. International design standards

Design	Standard
Steel structure	DNV-OS-C201 "Design of Offshore Steel Structures, General (WSD Method)" ASTM A131 "Standard Specification for Structural Steel for Ships"
Buckling	DNV Cl. Notes No. 30.1 "Buckling Strength Analysis of Bars And Frames, and Spherical Shells"
Fatigue	DNV-RP-C203 "Fatigue Design of Offshore Steel Structures"
Bolted connections	AISC "Steel Design Guide Series 16"
Environmental	DNV-RP-C205 "Environmental Conditions and Environmental Loads"

FEA model was the main tool for design. Engineers with operational experience extracted results from numerical calculations of most important load cases expected during the vessel transit and the conductor side launch.

The CG of the overhang piece was a concern from beginning, especially for the assembly onshore. A correction was made using a clump weight. Such decisions and other exceptional load cases were identified by a risk management process through the project life, which will be discussed in the Section 10.

Critical zones in the structure were refined with FEA local models to ensure structural capacity under harsh environmental conditions. Despite the survival condition defined in the Table 1, a more conservative approach was considered from DNV-RP-C205.

A final step in the design was the modularization of the structure in order to turn the equipment transportable. Bolted connections were specified according to AISC codes.

8. Handling and launching long and heavy casings offshore

Every time the oceangoing barge was employed, the Shuttle System (Figure 4) was installed and used with success. Shuttle System is a lift travelling over rails which translate a conductor casing from the storage/transit position to the barge's edge, when the overboarding occurs.



Figure 4. Shuttle System, previous handling and launching system

Executing the lift requires two near-equidistant points from the conductor's center of gravity (CG). Due to the geometry of COP's structure and the conductor position over the structure, equidistant points from CG would result in a lift positioned outside of deck's footprint, which means over the water. Any mechanical failure and maintenance could cause an oil spill or a man overboard .

To mitigate such risks the handling system was redesigned intended to roll the conductor instead of lifting it. The Shuttle System acted simultaneously as handling and launching equipments, while the new version was split in 2 isolated systems to handle and launch a conductor.

The handling devices (see Figure 5) travel on a rail underneath the row of casings. The travelling method was kept similar to the Shuttle System design, following the principle to change only what is mandatory. A pair of handling pins encloses the most outboard conductor and rolls it to the launching device.

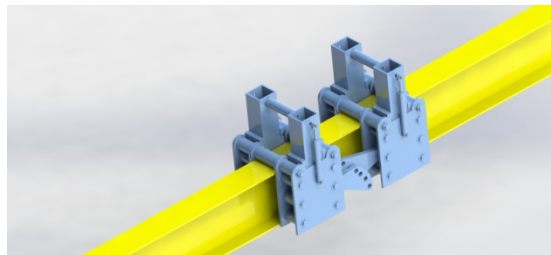


Figure 5. Handling system

The launching devices (see Figure 6) are fixed to the COP's structure and are considered a safe position until the overboard is authorized by the person in charge. The handover is constrained by both handling and launching equipments; consequently the conductor is unable to roll.



Figure 6. Launching system

Launch action is activated by synchronized rams, which turn the launch cradle with no return. The conductor rolls over a short ramp and free falls to the water exactly like from the barge. For more detailed information of the handling and launching sequence, see Figure 7 below.

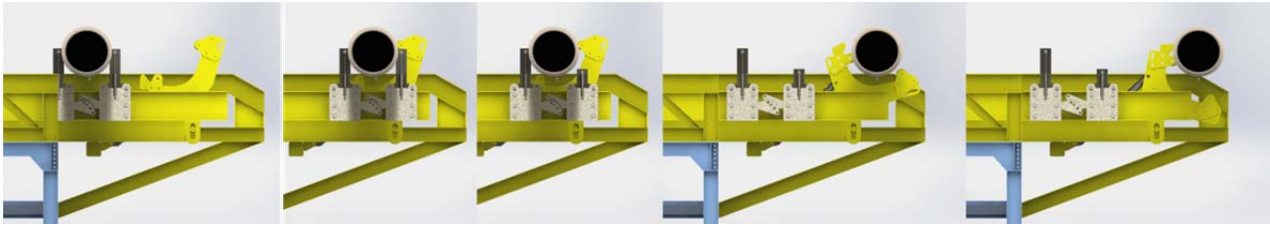


Figure 7. Handling and launching sequence, from left to right.

9. Work wire length

Engineering analysis after the free fall stage was more complex and faced some unusual modeling issues. Software Orcaflex was used for the overboarding simulation, including entrance in the water and the pendulum until the vertical position in the work wire, as demonstrated on figure 8.



Figure 8. Orcaflex program window

Work wire length and composition was the main study in Orcaflex, but other interesting results were analyzed. Preliminary modeling presented inconsistent results and highlighted issues related to:

- Discretization of conductor casing
- Discretization of work wire
- Time step in the numerical solution

The conductor was initially modeled as a single open top and open bottom buoy element. Apparent random slam forces during the free fall (while in the air) challenged this approach. Engineers started a sensitivity investigation splitting the conductor with several open buoy element attached as a single buoy element. Converging results of this detailed study showed the conductor had to be discretized in parts no longer than 1 meter as opposite of the single piece with 60 meters first proposed.

A similar incoherent behavior emerged in the conductor's pendulum movement between horizontal and vertical positions. Another sensitivity analysis was run in order to find an optimum segment length for the work wire. The overall simulation would consider 30 to 100 meters of work wire paid out when the conductor passes the splashzone and the default 3 meters segment was insufficient to provide stable results. In the end, segments 1 meter long converged to a reasonable behavior.

Both discretization issues resulted in a more refined model, which also meant a more computer demanding model. Then, more complexity was added when the conductor passed the splashzone and unexpected loads were found. The engineering team quickly noticed the issue was related to the speed the conductor reached the water. A default time step of 0.25 seconds allowed only 1 step of interaction between conductor and water.

A third sensitivity analysis was executed and results converged when time step was defined as 10^{-3} seconds. However after the splashzone, such small time step provided no gain to the model, therefore 2 different models were created: the splashzone and the pendulum.

With a validated model, the pendulum stage was analyzed with regards the work wire length and type of rope. In previous projects with the barge, a synthetic HMPE (Spectra or Dyneema) rope section was inserted between the work wire and the conductor, which proved to be beneficial to avoid shockloads and allow safer handling by the deck crew. The same conclusion was found in the current Orcaflex model and a 50 meters long rope is recommended.

A longer rope provoked undesirable shockloads due to time in free fall into the water. And a shorter rope increased the pendulum movement due to lack of damping effect by the water.

10. Risk management and HSE

The novelty characteristic of this design project demanded constant progress over unknowns. Naturally, during a NPD project life, such unknowns are uncovered and the team finds a more comfortable scenario. A consistent risk management process was implemented since beginning of the project, with all engineering team involved.

Risks were managed in 2 groups:

- Project Risks
- Operational Risks

First group of risks were related to the design progress, schedule fails, cost overruns, reworks, scope creeping, concurrent projects, etc. Weekly meetings were held with the team in order to discuss issues and potential risks forthcoming. Risks were identified, evaluated, prioritized and responses were planned accordingly. Second group of risks surrounded the designed equipment's performance, i.e., the ability to deliver an efficient operation in the field. Main concerns were naturally related to health, safety and environment (HSE). Different tools were used to ensure equipments and processes were developed in a safe way.

Failure Modes and Effect Analysis (FMEA) was a main tool, by instance, to perform small design changes in the handling and launching system, adding contingency or, even better, avoiding technical risks.

COP is a concept based on a field proven installation methodology, so it must repeat all positive learning and improve negative steps, mainly those related to increase operational safety.

11. Conclusions

The COP enables operators in Brazil, or any other place in the world, to pre-install conductors or other piles – same methodology is applicable for pile anchors or different pile foundations – in an efficient manner, reducing costs and improving supply chain to start a well.

Quick mobilization and demobilization fits to the Brazilian vessel market and logistics limitations. Cheaper resources instead of drilling rigs proved to be a positive trade-off for operators working in deepwater and ultra-deepwater. Driven conductors also showed good performance with regards to holding capacity both for axial and bending loads.

All these characteristics added to an increase on operational safety that allows the COP to be used on a routinely basis demanding a minimum lead time with short planning by the oil company, but followed by realistic added values for the well cost.

11. References

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