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Modifications to the Pipelay Vessel Solitaire for the Independence Trail Project

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Abstract

This paper describes the modifications to the pipelay vessel Solitaire to meet the installation requirements for installing the Independence Trail pipeline and steel catenary riser (SCR).

To meet these requirements it was necessary to increase the stinger length and strength. The tension capacity was doubled by means of new tensioners and a new abandonment and recovery (A&R) system using 4 wires simultaneously.

After manufacturing and installation of all equipment, an extensive testing program was performed to prepare the vessel for the installation of the Independence Trail pipeline and SCR.

Introduction

The perception of deep water changed significantly during the last two decades. In the beginning of the nineties, 1000 ft water depth was considered “deep”. Nowadays, laying pipe in water depths of 5000 ft is common practice. The Independence Trail pipeline was the next step in even deeper water for large diameters.

The pipelay vessel Solitaire, a dynamically positioned S-lay pipelay vessel with a length of 1300 ft (400 m) including stinger, was made suitable for this project during a 3-month conversion period in which she was upgraded.

Facts and figures

The Independence Trail Project (Enterprise Field Services L.C.C.) consists of a 24 inch gas export pipeline including a 20-inch SCR in the Gulf of Mexico.

The total pipeline length is 135 miles (217 km) in water depths ranging from 115 to 7940 ft (35 to 2420 m). Included in the scope was the installation of a flex-joint at start-up, SCR VIV strakes, buckle arrestors, two in-line double Tees and an in-line ball valve.

The pipeline transports gas from the Independence Hub Facility in Mississippi Canyon 920 to the West Delta 68-JP platform, and was installed using Allseas’ pipelay vessels Solitaire and Lorelay in 2006.

Upgrades

The 24 inch pipeline and 20 inch SCR in water depths of up to 8000 ft required a lay tension of 1450 kips (650 metric tons). Therefore the tension capacity of 1150 kips (525 metric tons) required an upgrade of the pipelay system and the abandonment and recovery (A&R) system.

Strain limitation in the catenary required a longer stinger, which made it necessary to have a larger radius combined with a steep departure angle.

When upgrading one part of the vessel, all interconnected parts had to follow.

Figure 1 - Overview of Solitaire’s aft – 2005 vs 1998

Stinger elongation 360 ft to 460 ft (110m to 140m)

The elongation of the stinger was necessary for both the steep departure angle and the increased tension capacity. The in-house design of the stinger started early 2004 with the anticipation of an increase in tension requirement; six months later the installation contract for the Independence Trail project made it a fact.

The three-section, 360 ft stinger was replaced by a four-section 460 ft stinger, in which the last two sections have been maintained (see figure 1). The new two sections are only connected to each other on the bottom side in order to divert the loads to the also new hang-off frame, and by doing so being able to use the existing stinger hinges and handling system.

The first stinger section is connected to the vessel by the stinger hinges and a rigid handling system. The second, third and fourth stinger sections are hinged to the first section and connected with cables to the new hang-off frame.

Figure 2 gives an overview of the new stinger and hang-off frame while Solitaire was being modified in dry-dock.

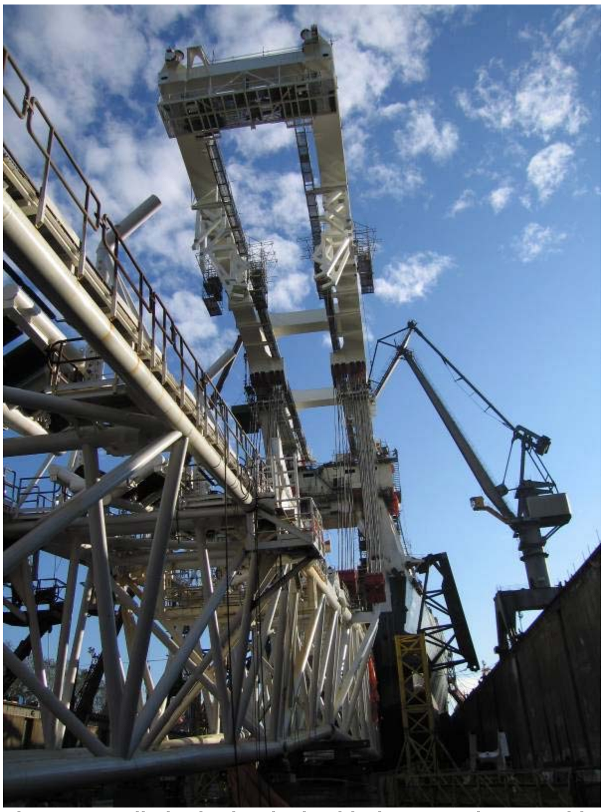

Figure 2 - Solitaire in dry dock with the new stinger and hang-off frame

Stinger rollerboxes

The guides on the stinger, the so-called rollerboxes, were redesigned in order to reduce peak loads of the pipe on the stinger. A "see-saw" type rollerbox was designed. In this design the load on the pipe is better distributed, all rollers are equally loaded, and the pipe runs more smoothly along the stinger.

The rollerboxes have a sturdier design to cope with the higher loads caused by the higher lay tensions.

Figure 3 – Overview of stinger and stinger hang-off frame

Stinger handling system

The stinger did not only become longer and stronger, but at the same time it became heavier and the centre of gravity moved more to the stinger tip. For this reason a frame was needed with an extended hang-off point at the aft of the vessel, in order to minimize the extra loading of the stinger. Figure 3 shows the hang-off frame used to support and handle the stinger.

The hang-off system consists of 4 winches in two pairs, in which the pairs are coupled for redundancy reasons, and a device to prevent slack rope. This slack rope could occur in case the stinger is unloaded in submerged condition and waves would move the vessel in such a way that the drag and the buoyancy forces on the stinger make the stinger weightless to the vessel. This situation is undesirable and therefore this system was placed onto the handling system.

The hang-off frame is made of high-tensile steel with a length of 200 ft (62 meters).

Aft ship reinforcement

Addition of the extra loads on the slenderly designed aft ship of Solitaire required reinforcement. The aft ship was strengthened mainly by means of extra buoyancy. The added buoyancy, shown in figure 4, has a buoyancy capacity of 8800 kips (4000 metric tons). This and the enlargement of the section area solved the strength issues in the aft ship.

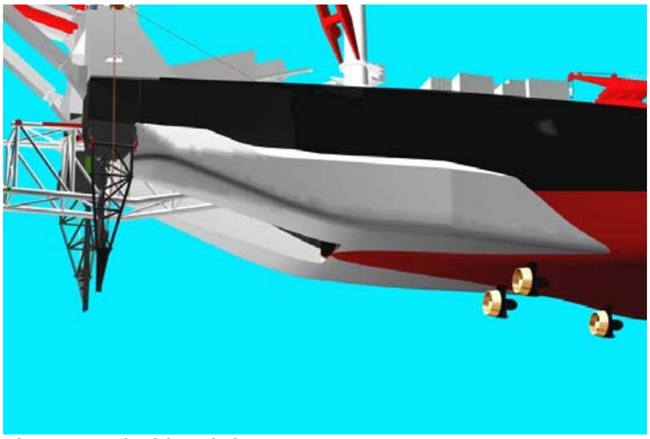

Figure 4 - Aft ship reinforcement

Tensioner replacement from 1150 kips to 2300 kips (525 metric tons to 1050 metric tons)

Solitaire not only required an increased tension capacity, this also needed to be achieved within the same geometrical restrictions of the existing tensioners (see figure 5).

To keep the length of one tensioner within limits, the clamp pressure was consequently increased. To assure the friction between tensioner and pipe, extensive testing of the tensioner shoes was carried out. Different materials and shapes of the shoes have been put to the test, which resulted in a guaranteed holding capacity on all pipe coatings in all conditions.

Figure 5 - Side by side comparison between old (right) and new tensioner (left)

Another important feature of such a machine is the chains on which the shoes are mounted. These chains are also used on the largest bulldozers. Since these chains are, as the shoes, a critical part of the tensioners, a break test was carried out. Each tensioner is equipped with four D11 Caterpillar chains, the largest available.

During the installation in Solitaire's firing line, the tight tolerances – about 1 inch clearance relative to existing structures – required some close looks.

The testing of critical parts in the design phase of the project resulted in a reliable tensioner that passed all the field tests in the first try. During commissioning, a load test of 960 kips (440 metric tons) per tensioner – an overload of 25% – showed that the machine indeed more than met its criteria.

A&R capacity upgrade 900 kips to 2300 kips (400 metric tons to 1050 metric tons)

Because the systems to hold on to the pipe were upgraded, the system to lay down the pipe also needed an increase in capacity. Normally the pipe is laid down with a steel cable on the seabed when the end of the project is reached or bad weather is approaching.

Because of the long length, nearly 16.000 ft (4850 m), and the required safe working load of 2300 kips (1050 metric tons) of the cable(s), one single cable could not be manufactured. Therefore it was chosen to use multiple cables simultaneously. The interaction between the cables has been a point of concern: hockling and entanglement were two focus points in the research phase. To minimize the interaction, two right handed and two left handed cables have been used, and theoretically this results in a neutral torque load at the end of the cable.

In the preparatory research phase, scaled tests have shown that it is possible to model and predict the behavior of steel wire cables. The cable behavior model has been used in the construction of a large simulation model that resembles the operation of releasing a pipe and retrieving the cables onto the vessel. As many examples have shown previously, releasing each cable individually and retrieving it to the vessel would have resulted in entanglement. Therefore such operation was banned and the cables were combined in a tool (A&R cable connector) that releases the pipe while keeping the cables together.

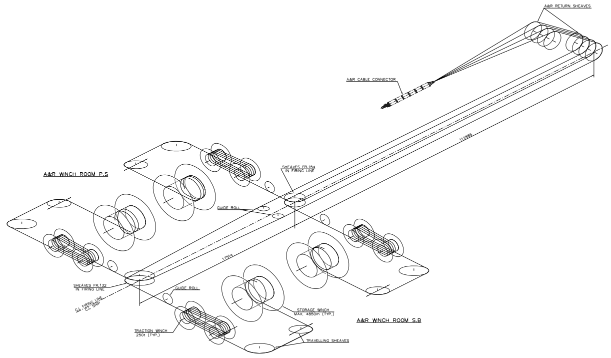

Figure 6 - A&R reeving diagram

The A&R cable connector (see figure 7) has the functions to keep the A&R cables under tension by its weight, to release and hook on to the pipe, and to provide information about the orientation of the tool. Although the cable system is theoretically torque balanced, any undesired rotation of the tool was foreseen. To control the rotation when it is deployed or recovered, the tension in each individual cable is monitored and adjusted.

The winches are conveniently placed midships and the cables run to the bow (see figure 6) where the cables are guided into the beadstall by a return sheave. For deep water the tension in the cable during an A&R operation is relatively constant, but for shallow water the tension can vary significantly. The elasticity and damping in the cable absorb the variations and prevent that the cables become slack.

Figure 7 - A&R cable connector in the beadstall

The A&R system consists of four parallel wire ropes that run from individual winches to a rigid connection on the A&R cable connector. Because the strands inside the wire rope are spirals and the rotation at both ends of the ropes is prevented, the rope generates tension induced torque (see figure 8).

A rope that is subjected to torque might form a loop which is known as hockling, and might result in kinking damage. The conditions for hockling, as predicted by the Greenhill criterion, depend on the rope properties and applied tension. Downscaled ropes have been put to test to measure their properties and verify the hockling criterion. It was concluded that the rope tension was not allowed to drop below 4 kips (2 metric tons) which has been safeguarded with a minimum A&R cable connector weight of 17 kips (8 metric tons).

Figure 8 - Stranded wire rope: tension induced torque.

Since the wire ropes' bottom ends are tight together, torque, rotation and load are coupled between the four ropes. Theoretically the system is balanced and the A&R cable connector has no rotation. However, there is always a mismatch in left and right handed rope properties; or external forces like water current may act on the system. In either case, the A&R cable connector will rotate and the ropes will rotate around each other; in other words, entanglement. For successful deployment, the degree of entanglement has to be stable and controllable by individual winch adjustment. A virtual multi-body dynamic model was developed and downscaled tests (figure 9) were performed, which predicted a stable system. It was also estimated that the A&R cable connector can be actively rotated over 360 degrees if the two equal-handed ropes are paid in or out with 4 inches (0.1 m) by the winches.

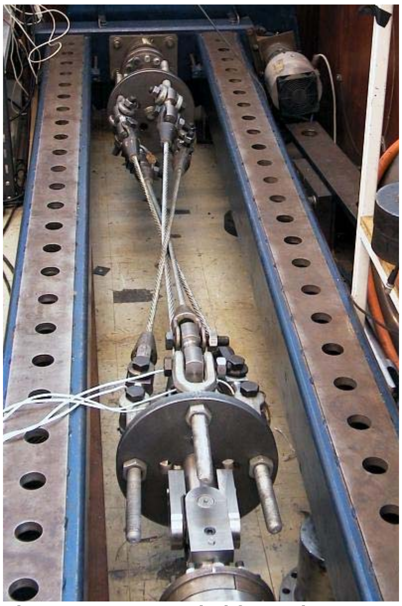

Figure 9 - Downscaled four-wire system: entanglement test

Commissioning

The last phase in the conversion was the commissioning of the systems. The new systems on board are so large in dimensions and new to the offshore industry that the tests were important, though limited time was available. The tensioners and the winches have been loaded with 125% of their maximum operational capacity. Also, various types of line pipe coating have been tested in the tensioners to verify the grip on the pipe.

Figure 10 - A&R cable connector on the stinger

Following the load tests, the A&R system was tested with the deployment of the A&R cable connector. The connector has been pulled over the stinger and lowered to a depth of 7700 ft (2350 m). On the way down all ROV functions such as manually opening the release hooks, closing and opening the latch, have been successfully tested.

During the deployment it was noticed that when one or two cables are slack and the connector has rotated 13 times, the system was controllable. The target was to obtain zero rotation at 7700 ft (2350 m), and this was successfully achieved. This target has been set to be able to pick up a pipe from the seabed without having the cable entangled.

Figure 11 - A&R cable connector on stinger section 3

Conclusions

The offshore industry is a very innovative environment with many interesting challenges, forcing contractors to innovate, to create new tools and techniques.

Several developments were combined successfully in the modification of Solitaire in 2005, among which a doubling of her holding capacity within the constraints of an existing ship, considerable vessel reinforcement and buoyancy addition, an improved roller box design which provided more gradual pipe bending on the stinger, combined A&R cables which was necessary due to manufacturing constraints, and successful provisions against cable hockling and entanglement.

The deployment of all these new features inevitably caused teething problems and therefore operational time loss early 2006, but this phase was followed by entirely successful operation since.

Modifications of the nature described in this paper are market driven – by a desire to meet the clients' demands as frontiers are moved.

With these new techniques, offshore pipeline installation technology has made a big step ahead and is ready for the future.

Acknowledgements

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