Abstract.
A new and safer, high load capacity well construction concept has been developed. This new well foundation system as installed at a Norwegian Sea well location by Det norske oljeselskap ASA, is described herein, as well as its use and recovery. Heavy Blow Out Preventers (BOP) are normally used on drilling rigs designed for deep water and arctic applications, and heavier BOPs will have a negative impact on the stability of the well head. To mitigate these negative impacts, a new suction anchor type well foundation concept; CAN (Conductor Anchor Node) has been developed. The CAN unit provides sufficient load capacity for safely carrying heavy BOPs as well as X-Mas trees, thus protecting the well from fatigue capacity “consumption” in the drilling phase. The use of the concept will also reduce cuttings and cement disposal to the sea, which may be further important aspects in arctic and sensitive marine environment areas.

The CAN will also mitigate the risks of the well becoming over-loaded by undesired, accidental loads, e.g.: as a result of a rig drive off/drift off situation. This is achieved by mobilising substantial carrying capacity from the soil through the CAN’s large cross sectional area and captured soil mass. This is an important aspect in view of risk mitigation and improving possibilities of applying contingency means in case of undesired events or disasters, such as the Macondo case.

The concept offers significant advantages in reducing rig time; as it enables pre-rig conductor installation, thus reducing top-hole construction costs and rig failure risk exposure. The concept’s viability and advantages have been demonstrated by a number of full scale applications ranging from 270 m to 1 150m water depth on the Norwegian Continental Shelf.

The CAN will be a facilitator for safe jetting of conductors (only short length conductor needed), as well as being an enabler for achieving successful cement jobs (if installed by drilling and cementing), as the conductor remains supported and motionless during cement set-up.

Introduction.
As drilling rigs day rates increase, there is a growing need of reducing the required rig time to drill the wells. For drilling the top-hole section (30” & 20” casings) of the wells, no pressure control and fluids return to the drilling unit is needed, or possible. Hence, this part of the well operations lends itself to use of alternative, smaller well construction units, to save rig time through pre-rig well construction. For this purpose a more efficient, vessel friendly conductor installation method is needed.
Also, field cases have clearly demonstrated that the present well design does not carry any contingency load capacity for accidental loads. Such loads may e.g.: be caused by rig drive off or drift off situations, which in most cases will lead to well head /conductor failures, and in turn loss of the entire well.

To facilitate efficient pre-rig well construction and prevent accidental load caused well damages, a new design philosophy has been developed, based on the use of a suction anchor type of well foundation named CAN (Conductor Anchor Node). The CAN structure will guide the conductor during its installation, as well as giving it mechanical support after installation, such that the conductor is turned into a very high lateral load capacity and bending stiff construction. In this way, the “system weak link” is transferred from below to above the BOP. Hence, accidental peak loads will have to be “consumed” by the Marine Riser and the Flex joint, which in extreme cases may also suffer damage. However, these parts are all accessible and replaceable, leaving an undamaged BOP and well.

**Technology description.**

The CAN is a specially designed suction anchor type of structure. It consists basically of an open ended (down) cylindrical outer shell with a strong lid section and a concentric centre pipe / conductor guide, which extends as deep as the CAN skirt. This construction allows installation without water leakage through the CAN centre, as the conductor guide will penetrate as deep as the CAN skirt into the soil, and thus a closed in volume is attained without the use of a centre pipe lid.

A typical CAN weight will be 60-80 tons, with following outline dimensions: D = 5-6 m, H = 8-12m, giving a soil penetration capacity of up to 10-11m.

The CAN is pre-installed by a fit for purpose DP-vessel, fitted with a heave compensated crane, suitable for the job. At location, the vessel crane picks up and runs the CAN to near sea bed, where it is switched to Active Heave Compensated (AHC) mode to set down and attain a controlled CAN self-penetration. There after the ROV equipped with a suitable pump is docked to the CAN to pump out the captured water, thus reducing the CAN internal pressure. The pressure differential attained in this way will in turn generate a net downwards directed force, which will push the CAN further into the sediments. Through the large lid area, substantial push-in forces can be mobilised by applying moderate differential pressures, e.g.: on a D = 6m CAN, having a nearly 30m² lid area, a ΔP of 2 bar will generate a CAN push-in force of nearly 600 ton!
To optimise the CAN design, specific location soil information is utilised to optimise the CAN’s D and H dimensions to achieve needed well load capacity. Through the CAN’s large contact area to the soil, the entire BOP and casing loads may be carried by the CAN.

Once the CAN is in place, the same installation vessel may be used to undertake the conductor installation. As the CAN is designed to be the main load carrying member, the conductor may now be shortened to say 3 joints (30-35m). The conductor is pre-assembled onshore into one joint (by welding), such that by a simple crane operation, the conductor is lifted horizontally off the deck and into the water, where it is up-righted to a vertical position before it is run and stabbed into the CAN conductor guide to self-penetrate. Thereafter, a hydraulic hammer is run to drive the conductor into the soil until landing its WHH in the CAN. In this way the conductor is “installed by wire”, which is a much more cost efficient method than drilling and cementing. Fig. 1. illustrates a typical CAN / Conductor stack-up.

If so preferred for various reasons, the conductor may also be installed through the CAN by the Drilling Unit, by jetting. It is to be noted that the CAN will facilitate safe and predictable conductor jetting, as shorter conductor strings will be needed. Hence, the inherent risks of high conductor stick up have been mitigated by use of the CAN, as well as risks of insufficient load capacity. By using the CAN, conductor jetting becomes a predictable, robust and possibly the most cost efficient conductor installation alternative available.

Substantial advantages may also be attained by using a pre-installed CAN, through which the conductor is drilled for, installed and subsequently cemented by the rig, as shown in Fig. 2. below:

Fig. 2. Conventional and CAN conductor cementation comparison
To be especially noted from above is that the CAN will facilitate superior conductor load capacity, in using shorter conductor and less cement. Improved cement curing conditions are also provided by:

- Motionless conductor, being “captured” by the CAN’s conductor guide pipe.
- Low temperature curing conditions at sea bed avoided (no need for return to sea bed)

The CAN based well design offers a number of technical advantages, e.g.:

- High axial load capacity – suitable for the heaviest BOPs
- High lateral load capacity:
  - Increased bending stiffness and reduced fatigue “consumption” in the well drilling phase.
  - Significantly increased accidental load capacity – well loss risk mitigation.
- Pre-rig well construction enabled:
  - Reduced rig time & accelerated production
  - Reduced top-hole construction costs
- Reduced cuttings and cement disposal (if drilling and cementing)
- Enables safe conductor installation by jetting
- Reduced environmental foot print (less CO2 emission, NOX, etc.)
- Enables Pre-rig well construction

### Operational experience

**CAN Installation**

CAN units have been installed on a number of NCS well locations, ranging from 270m to 1150m water depth and it has been combined with rig jetted conductors, rig drilled and cemented conductor as well as driven, vessel installed conductor. For the subject Norwegian Sea well, which was to be drilled at a very soft sea bed location, the main objective of the CAN installation was to ensure that a high load capacity conductor was attained. This was needed to prepare for the 6th Gen rig Aker Barents’ heavy BOP, weighing nearly 400 ton.

The CAN installation was performed uneventfully, within a total vessel location time of less than 20 Hrs. As evident from Fig. 3., the CAN was equipped with 2 transponder units for geographical location control and for CAN inclination control during installation. The requirements to CAN inclination ($\leq 1^\circ$) and placement accuracy were all met within acceptable margins. Fig 4 below compares the Predicted and Uncorrected Observed Penetration Resistance as measured during the installation.

The max installation pressure differential ($\Delta P$) amounted to about 2 bar, increasing gradually from 1 bar. $\Delta P$ of 2 bar is equivalent to about 550 ton push in force, which also implies that the CAN was tested to take a vertical load of that magnitude!

![Fig. 3. CAN being run through the Splash zone](image)
A near full CAN penetration (10.5m vs. 11m) was also achieved. The explanation of this difference is most likely that the soil displaced by the CAN steel skirt penetration was moved to the CAN inside, due to the pressure differential. This volume corresponds to a “mud heave” inside the CAN of about 0.5 m.

The installation experience from this well show that an installation weather window of $\leq 3.5 \text{ m H}_S$ would apply for the selected vessel. This window is needed for about 4 hours, to ensure bringing the CAN safely off deck and through the splash zone. Once the CAN is through the splash zone, heavier weather conditions may be accepted.

All ROV operations were successfully performed, proving the capability of the Vessel / ROV / Crane cooperation. The rig arrived location after the CAN was in place, where after the conductor was drilled for, installed and cemented uneventfully. In spite of the soft sea bed formation, full cement returns could be taken to sea bed through the CAN, thus cementing the conductor into the CAN conductor guide. This experience shows that for conductor / CAN cement jobs, the excess cement volume can be reduced from 200 to 0%. This will dramatically reduce the total cement volume, mixing and pumping time. The post well CAN recovery showed that an excellent cement quality had been attained to top of CAN, which most likely can be attributed to optimum cementing conditions: No pipe movements or cement stirring during cement setting.

**CAN recovery**

Following the well drilling operations as per plan, the well was plugged by the rig prior to leaving the 20” & 30” conductor cutting and CAN recovery operations to be performed by a fit for purpose vessel.

The cutting operations were performed as per plan; i.e.: cutting the 20” + 30” in one cutting sweep below the conductor guide pipe. Thereafter the CAN recovery operations were commenced by reversing the installation process: The ROV now pumping water into the CAN. After pumping the CAN out about 60% of its total embedded length, the remaining CAN length had to be pumped / lifted out of the soil. After being freed from the sea bed, the CAN including the cut 30” + 20” was lifted to surface, as shown in Fig. 5.

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**Fig. 4. Predicted and Uncorrected Observed Penetration Resistance**

**Fig. 5. CAN recovered to surface**
Bumper bars had been installed on board the vessel to catch the CAN when swinging it in over the deck, and set it on the planked deck down in a controlled manner, as shown in Fig. 6. Noticeable was the about 10 cm thick clay layer on the CAN outside. This demonstrates the presence of high steel/soil friction, as the shear by pull out had taken place out in the soil and not along the CAN steel periphery.

After chaining the CAN/conductor unit down and sea fastening it to the deck, it was transported to shore by the vessel. The CAN was placed in a horizontal position on the dock side, where the 30” conductor / 20” strings and Well Head assemblies were separated from the CAN. Thereafter the CAN was cleaned and readied for the next well foundation operation. This operation demonstrated that the CAN is a versatile, rugged unit, which may be reused for a number of well installations.

**HSE performance**

The vessel operations were all well prepared with risk assessment and HIRA (Hazard Identification and Risk Assessment) sessions. The CAN installation operations were performed without any HSE related incidents, and have demonstrated that the CAN operations may be performed safely and with very few manual operations. Previous operations have also demonstrated the conductor may be run “hands free”, which is a significant advantage compared to handling large diameter pipe on the drill floor of conventional rigs. Hence, it may be concluded that the CAN concept offers improved work conditions for the rig crew, by transferring the conductor handling from the rig to a “hands-off” operation on the vessel.

Further, it is concluded that conductor installation by vessels (as enabled by the CAN) will reduce the “environmental foot print” for conductor installation through use of smaller vessels with reduced CO₂ and NOX emission, as well as reduced cuttings and cement disposal.

**Conclusions**

The CAN concept opens new possibilities for safer and more cost efficient well construction. By means of the CAN, higher load capacity wells (conductors) can be installed than attainable with conventional technology. Ample accidental load capacity is provided by the CAN’s superior bending stiffness, such that any accidental load impacts will be directed above the BOP.

Its application in arctic and cold climate will give several important advantages, such as reduced conductor length, giving reduced cement volume, shorter cement jobs and reduced waiting on cement. Also an improved cement quality environment is created through motionless conductor whilst cement setting and no requirement to cement in the extreme low temperature environment at sea bed. The conductor installation will also have a reduced environmental foot print compared to conventional rig installation.

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