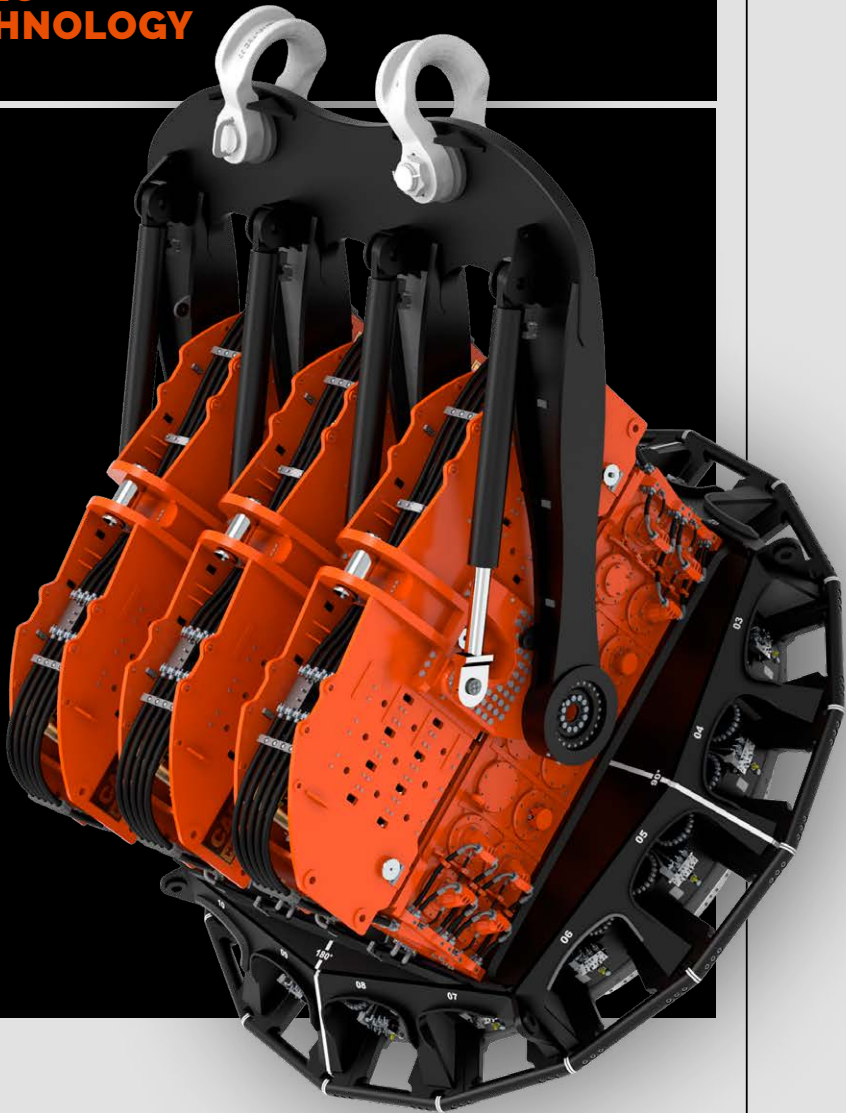


CAPE
HOLLAND

**OFFSHORE
VIBRO
TECHNOLOGY**



CONTENT

WE ARE PASSIONATE ABOUT PILING, WE CONTINUOUSLY IMPROVE THE PERFORMANCE OF THE OFFSHORE VIBRO TECHNOLOGY: FASTER, EASIER, SMOOTHER AND MORE SUSTAINABLE. WE LOVE TO CONTRIBUTE TO GOOD VIBRATIONS.

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01 VIBRO DRIVING

THE EVER-INCREASING DEMAND FOR REDUCING THE LEVELISED COST OF ENERGY AND PROTECTING THE UNDERWATER WILDLIFE, HAS TRIGGERED OUT OF THE BOX THINKING

In the search for alternative ways to make foundation installations quieter, faster and easier, the offshore vibro driving technology has developed in leaps and bounds over the past decades. The ever-increasing demand for reducing the Levelised Cost of Energy and protecting the underwater wildlife, has triggered out of the box thinking for the foundation pile installation.

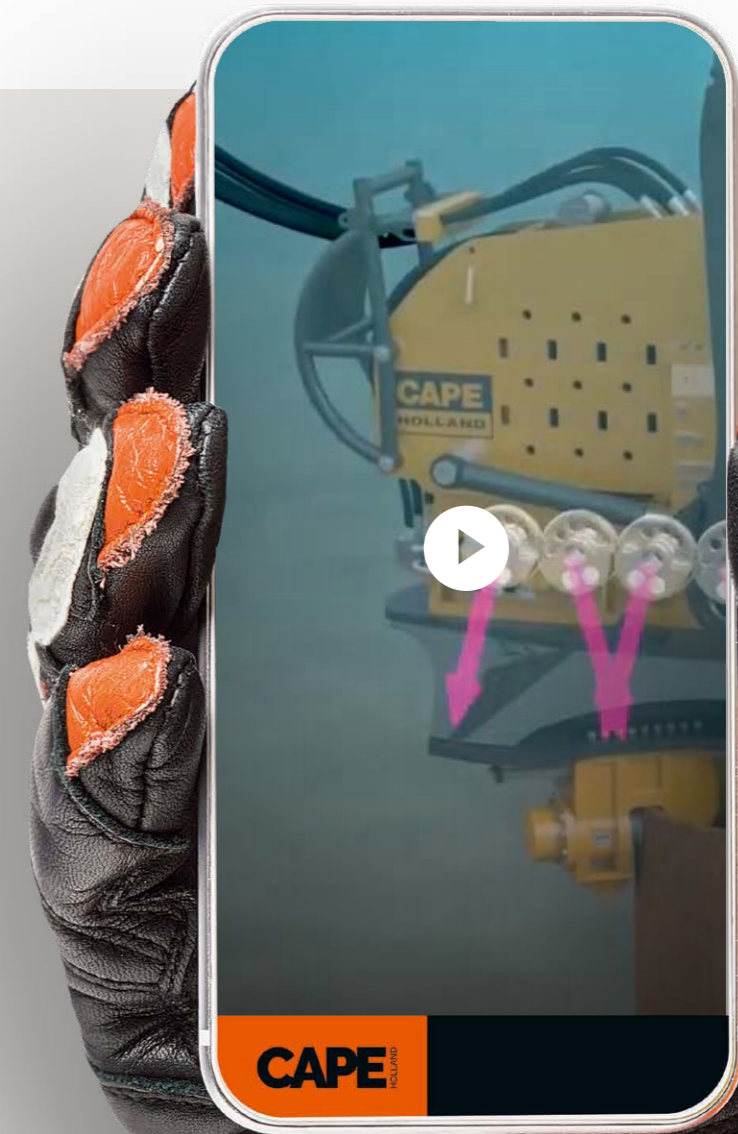
Vibro driving is a technology whereby a pile is moved up and down (amplitude) in a vertical direction which causes a temporary reduction in soil resistance of the soil immediately underneath and along the shaft of the pile. Due to this temporary reduction in soil resistance, the pile is lowered by gravity due to the weight of the pile and the vibro tool on top. As long as the pile is moving more than the surrounding soil, further penetration will be the result. As cohesive soils like clay have a higher more damping factor than a granular soil like sand, the performance in the granular soils is generally more efficient. Once the vibro is turned off, the soil is regaining most of its strength immediately. The rest of the setup of the soil will be regained over time.

In order to be able to vibrate the pile in a

vertical motion, it is paramount that the vibro tool has a fixed connection to the pile. This is normally achieved by hydraulic clamps. This fixed connection brings a number of added advantages to this installation method, like the ability to extract piles, prevent pile run, controlled installation without requiring a gripper system or piling frame.

The main source of noise under water comes from the pile itself. The vibro driving technology causes the pile to deform less whereby the generated noise stays below the limits set for impact driving, even without any noise mitigation measures like bubble curtains.

The two controls the operator can manipulate during pile driving to control the penetration are frequency and line pull. The operating frequency is between 900 and 1,400 RPM or between 15 and 23 Hz. The line pull determines the rate of penetration and the amount of static weight that is pushing down on the pile. This later can also work in the opposite way, i.e. with more line pull the pile can also be lifted which can help the installation or verticality corrections or be used for extraction.



WATCH THE VIBRO WORKING PRINCIPLE HERE



02

WE GO BACK 1930

THE ORIGIN OF VIBRO DRIVING GOES BACK TO THE 1930'S

It became more common offshore about towards the end of last century, when onshore vibro hammers were used to install relatively small piles. Since then, the largest land vibro hammers have been used occasionally, sometimes combining several of them for larger diameters or when more power was required. The current world record is currently set by piles with a diameter of 30 metres driven with a multiple linked vibro in China!

In 2012 CAPE Holland configured a multiple hammer consisting of four of the largest land hammers available at the time to drive monopiles for an offshore windfarm for the very first time. It became immediately apparent that the added

benefits the vibro tool could bring to the offshore industry would require a dedicated offshore vibro tool.

CAPE Holland went to work to build the first ever offshore dedicated Vibro Lifting Tool which combined the driving power of the vibro hammer with the lifting and upending capabilities of a handling tool. This latter requires the tool to be certified for offshore lifting. The CAPE Vibro Lifting Tool (VLT) was born.

Riffgat Offshore Wind Farm, 2012. The first ever monopiles driven with a vibro hammer in offshore wind.



03

CAPE VLT APPLICATIONS

**OVER THE LAST DECADES,
THE CAPE VLT HAS BUILT UP AN
EXTENSIVE TRACK RECORD**

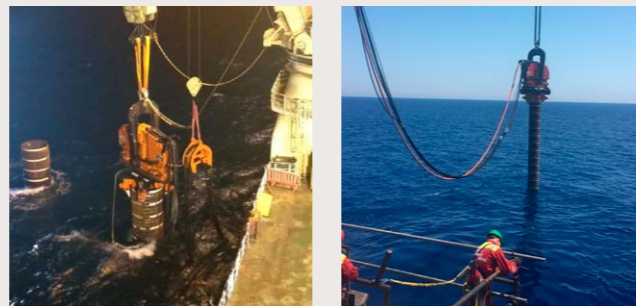
Since its first commercial project in 2015, the CAPE VLT has accumulated an extensive track record with highly efficient upending, positioning installation and extraction of offshore and nearshore piles. Using various CAPE VLT configurations and pile clamping systems a large range monopiles, pin-, jacket-, and anchor piles have been installed. The CAPE VLT has also been used for removal of piles during test and decommissioning projects.

MONOPILE INSTALLATION



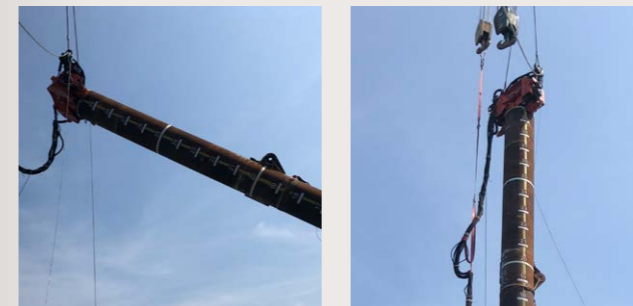
The offshore wind industry is growing and with wind farms moving into ever deeper waters and with more powerful turbines, the size of monopiles is constantly increasing substantially. Installing these large diameter piles can be a challenge due to their size and large weight and requires powerful and reliable tools. The CAPE VLT is ready to install even the largest monopiles in the market at the moment and for the foreseeable future.

PIN/JACKET PILE INSTALLATION



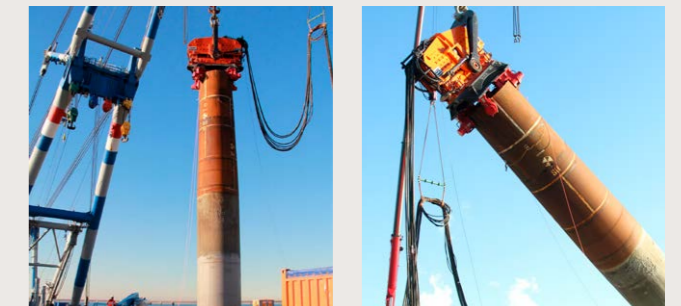
Large monopiles are currently dominating the offshore wind market, but as the shift to deeper water and larger turbines continues, jackets and tripods may be chosen more often as foundation type. For the installation of these foundations CAPE Holland can contribute its fast experiences and proven technology from the oil and gas market, but also from the first Offshore Wind Farm projects it has been working on.

ANCHOR PILE INSTALLATION



Anchor piles have been around for a long time to securely hold offshore floaters in place for the oil and gas industry. Compared to other anchoring solutions, such as drag embedded anchors, piles bring various benefits as they can transfer high loads not only horizontally, but also vertically and in multiple directions. That allows mooring of any floating structure design, such as Semi-Subs, SPARs, FPSOs and TLPs with the smallest footprint possible and therefore also ideal for floating structures for renewable energy.

DECOMMISSIONING



The vibro lifting technology has been proven as an ideal way for pile extraction. Just think of almost any large project on land where sheet piles are being used to create lateral support to be able to excavate areas for construction works. Towards the end of the project, which sometimes takes several years, sheet piles are being removed with a vibro hammer in most cases. The same can be done for offshore piles. CAPE Holland has proved this capability for large diameter piles offshore on a number of projects.

04

MAIN ADVANTAGES OF VIBRO DRIVING

THE VIBRO TECHNOLOGY IS VERY ATTRACTIVE FOR OFFSHORE APPLICATIONS

Vibro driving uses a completely different principle for driving a pile into the soil than other installation methods like impact driving or drilling. Bringing the pile in vertical vibration changes the behaviour of the soil to the advantage of using gravity to aid the pile driving instead of extreme high impact blows or time consuming drilling. The fixed connection to the pile that makes it possible to move the pile up and down at a high frequency brings with it some additional major benefits.

WHY WE LOVE VIBRO



01 FAST PENETRATION

The penetration speed of the vibro technology can be up to 10 times quicker than impact driving resulting in much shorter pile driving times.



02 LOW NOISE EMISSION

Noise mitigation is not required as sound levels of vibro driving are substantially lower than impact driving.



03 EXTRACTION POSSIBLE

With the typical capability of vibro driving to reduce the soil resistance in combination with a fixed connection to the pile it is also possible to extract piles. This is a great advantage for decommissioning, correcting tolerances, retract and re-install after hitting a boulder. Also the use of temporary piles which can be used for starter piles for pipe or cable laying is possible.



04 LOW INDUCED FATIGUE

Increase of design life of monopiles due to different energy impact. Although the frequency of the vibro is higher than with impact driving, the accelerations induced are more than a factor 100 less. Pile design could be greatly optimised for vibro driving leading to further reduction of costs. This is not just for the primary steel with thinner wall thicknesses but also for certain parts of the secondary steel which could be added to the primary steel.



05 SUBSEA COMPATIBLE

Vibro technology subsea is just as effective as above water which makes the CAPE VLT also the ideal tool for installing pin piles for jacket foundations for wind turbine generators and substations but also for anchor piles for the floating renewables.

05 WHY WE LOVE THE CAPE VLT

ADVANTAGES OF THE CAPE VIBRO LIFTING TOOL

01
**UPENDING,
LIFTING, DRIVING
IN SINGLE
OPERATION**



The combination of a certified lifting tool and a vibro hammer results in a single tool which can be used to upend a horizontal stored pile, lift it into the installation position and start driving it straight away without any tool changes or need to support the pile horizontally.

02
**IN COMBINATION
WITH DP
OPERATED VESSEL
THE FASTEST WAY
OF INSTALLING
MONOPILES**



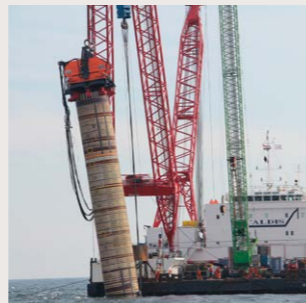
The CAPE VLT in combination with a floating DP vessel is the fastest and most cost effective way of installing monopiles. Multiple pile installations per day are possible.

03
**NO NEED FOR
GRIPPER OR
INSTALLATION
FRAME**



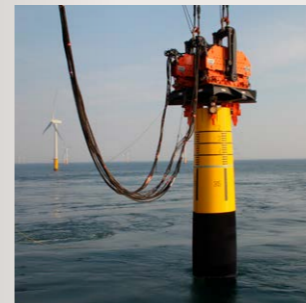
A pile fixed to the CAPE VLT and hanging in the crane does not need horizontal support during installation. A seabed installation frame or a (motion compensated) gripper can be a thing of the past, saving massive investments, but also significant offshore time and deck space.

04
**VERTICALITY
MONITORING
DURING DRIVING**



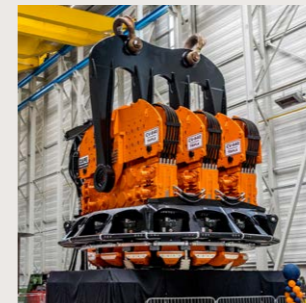
The verticality is monitored during driving and can be corrected easily by movement of the crane hook or gripper system. With DP vessels with a free hanging CAPE VLT, the corrections can even be made by just using the DP system to move the hook position.

05
**CONTROLLED
INSTALLATION**



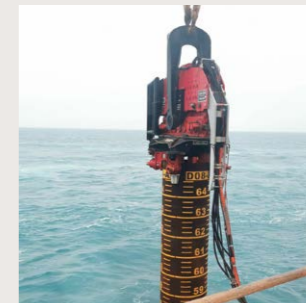
With the CAPE VLT hanging in the crane and the pile fixed to the CAPE VLT the contractor is in full control of the installation. Penetration speed, verticality and final height tolerance can all be controlled and corrected.

06
**MODULAR
DESIGN**



The modular design of the CAPE VLT provides a great freedom in configuring the perfect tool for the job. Differences in required performance, diameter, pile top or hook load capacity can all be catered for.

07
**ELIMINATE PILE
RUN/DROP FALL**



With the hydraulic clamping system the pile is always fixed to the CAPE VLT and when held in the crane during driving, a drop fall or pile run is eliminated. Additionally, the penetration speed and vertical height tolerance are fully controlled as well when load is kept in the crane.

08
**NO DIAMETER
LIMITATION**



A CAPE VLT-Single can already drive large diameter piles, but by adding more vibro units together, an even larger tool can be configured. This can be done in different ways which makes it possible to drive pretty much any diameter. The world record is a 30m diameter caisson in China.

06

THE CAPE VLT EXPLAINED

UPEND
FORK

SUPPRESSOR

GEAR
BOX

BASE
FRAME

CLAMPING
SYSTEM



LIKE A TRADITIONAL VIBRO HAMMER, THE CAPE VIBRO LIFTING TOOL HAS 3 BASIC COMPONENT BEING:

- Gearbox with the eccentric gears to generate the vibration.
- Suppressor which contains dampers to minimise the vibrations from the gearbox going into the crane.
- Clamps to fix the vibro tool to the pile.

THE CAPE VLT HAS SOME ADDED COMPONENTS TO TURN THE VIBRO HAMMER INTO THE VIBRO LIFTING TOOL:

- Upend Fork in order to rotate the tool to pick up a stored pile and upend it to a vertical position. Or in reverse for decommissioning.
- Patented lock system within the suppressor housing to lock the suppressor to the gearbox during lifting (bypassing the dampers) making the tool certifiable as an Offshore Lifting Appliance under the Lloyd's Register Code for Lifting Appliances in a Marine Environment (CLAME).
- CAPE Inclino System which accurately monitors the inclination of the tool and pile during driving.
- CAPE Monitoring System which monitors all parameters of the CAPE VLT during operation like the pressures, flows and accelerations.

6.1 FAST

VIBRO DRIVING USUALLY IS A VERY QUICK WAY OF DRIVING PILES INTO THE SOIL. IT CAN BE UP TO 10 TIMES QUICKER, PARTICULARLY IN SANDS

But the most time saving can be get from the logistical time savings as not having to use a separate tool for upending which than has to be removed before the impact hammer is picked up and placed on the pile. Not forgetting that to be able to remove the upending tool, the pile first has to be supported in a gripper of installation frame. Placing the pile in such gripper of frame also take time before the upend tool can be removed. During this time the gripper or frame has to be able to withstand the overturning force of the pile which partly determines the weather window. With free hanging installation, the pile can be lowered straight to the installation position without having to spend time placing it in a frame. Driving

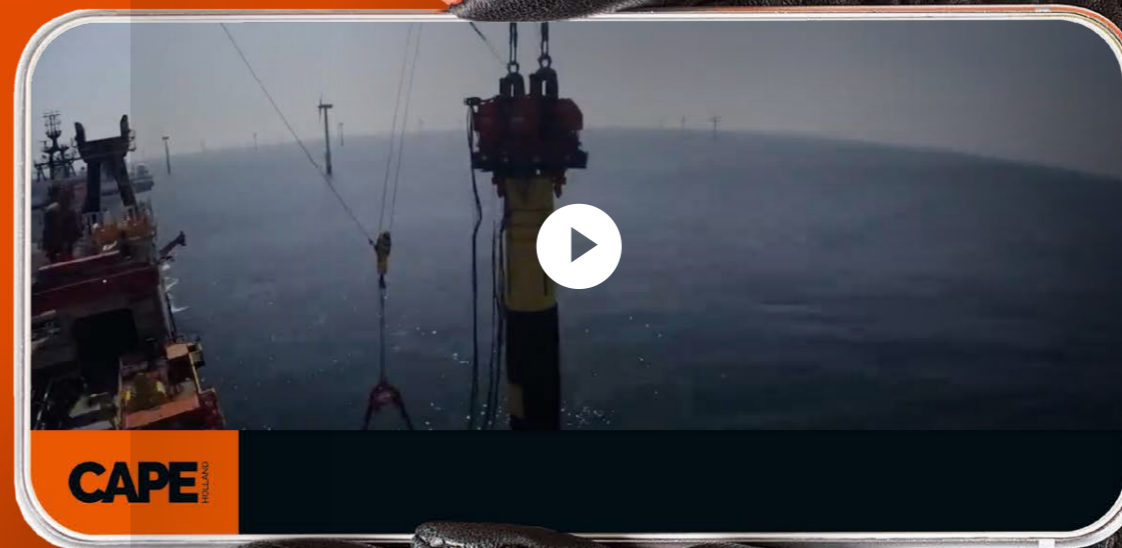
can then commence immediately. The fastest method of pile installation will therefore be the combination of free hanging installation with a floating DP vessel. The time saved of not anchoring-out and in or jacking-up and down is huge and then not having to position and operate a (motion compensated) gripper of sea bed installation frame again save a significant amount of time.

Primary and secondary pile guides aid stabbing the CAPE VLT on the pile for both horizontal and vertical positioned piles. In challenging conditions skidding systems can be added for easy stabbing of piles, saving time on aligning the CAPE VLT

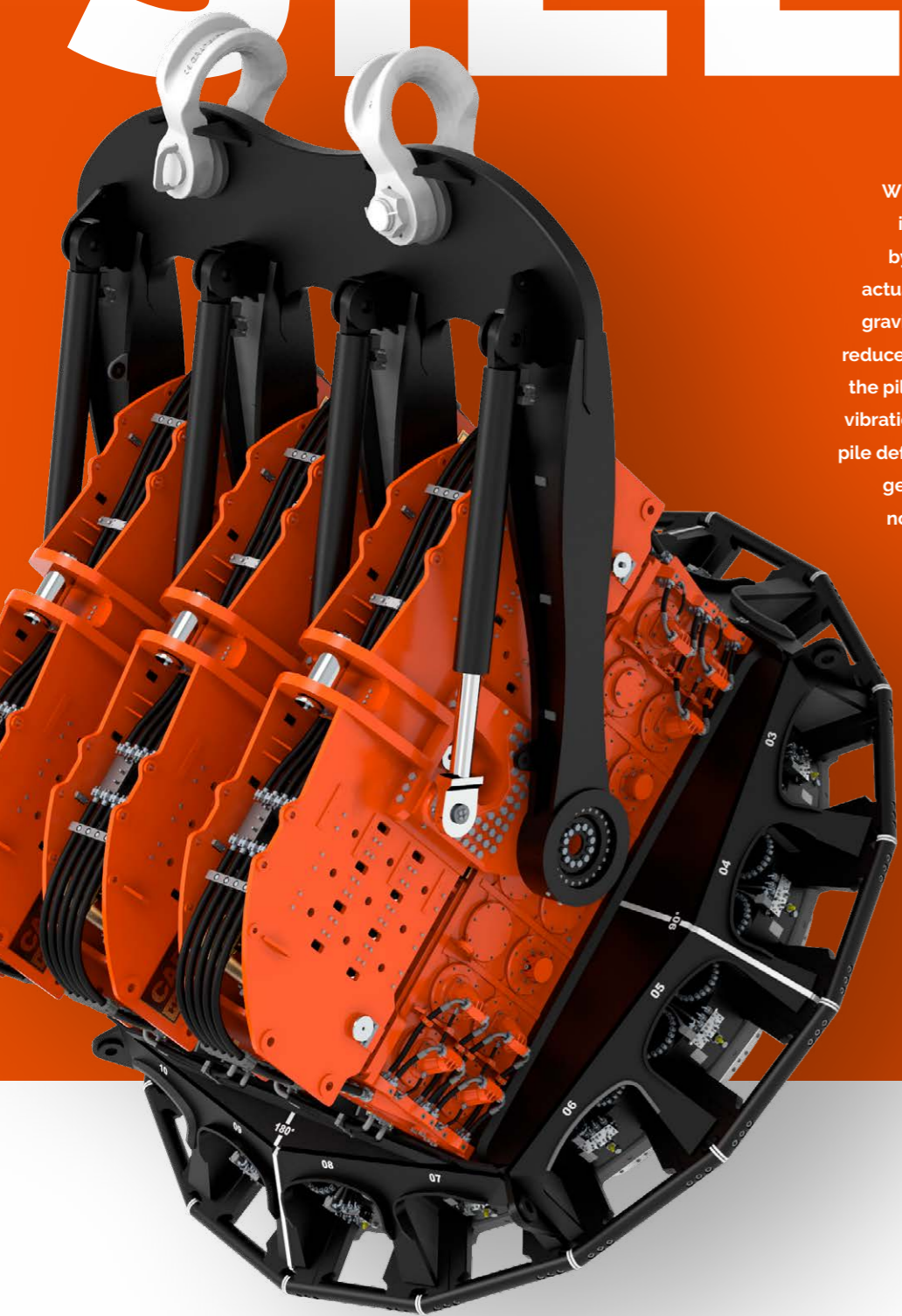


THE RIGHT COMBINATION OF FREQUENCY AND LINE PULL WILL ACHIEVE THE MOST EFFECTIVE PENETRATION SPEED

WATCH THE VIBRO INSTALLATION METHOD HERE



6.2 SILENT



With vibro driving, the pile is not forced into the soil by high energy blows, but actually sinks into the soil by gravity due to the temporary reduced soil resistance around the pile caused by the vertical vibrations. This means that the pile deforms less and therefore generates substantial less noise than impact driving.

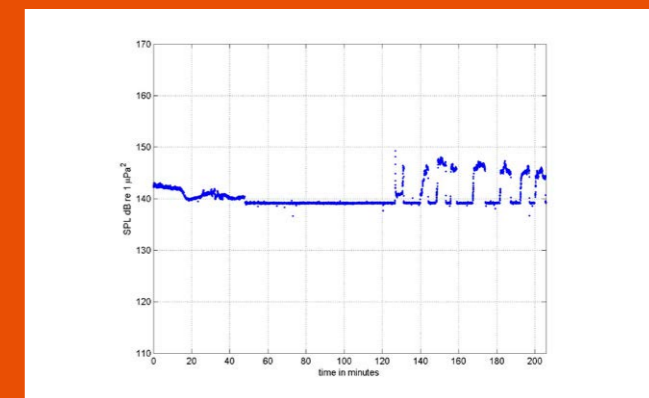
UNDER WATER NOISE

With vibro driving, the pile is not forced into the soil by high energy blows, but actually sinks into the soil by gravity due to the temporary reduced soil resistance around the pile caused by the vertical vibrations. This means that the pile deforms less and therefore generates substantial less noise than impact driving. The sound levels stay below the levels set by the BSH in Germany for impact driving, even without any noise mitigation measures like bubble curtains.

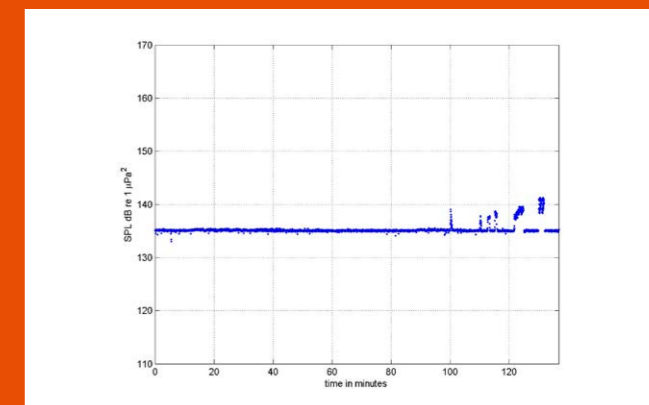
During a monopile installation project in the German part of the North Sea where measurements were taken, the levels were just above the background noise levels when no construction took place. This background noise comes mainly from shipping and other sound sources.

During another monopile installation project in the Dutch part of the North Sea with a Heavy Lift Vessel, the noise levels were hardly noticed due to the noise generated from the DP thrusters and a nearby Crew Transfer Vessel. These vessel noise emissions are a continuous noise source, similar to the vibro driver. The graph below shows the sound levels in the frequency spectrum whereby it can be seen that the sound levels are below the back ground noise at most frequencies and that only between 40 and 800 Hz the vibro noise is marginally higher than the other noise.

Sound level @750m in clay



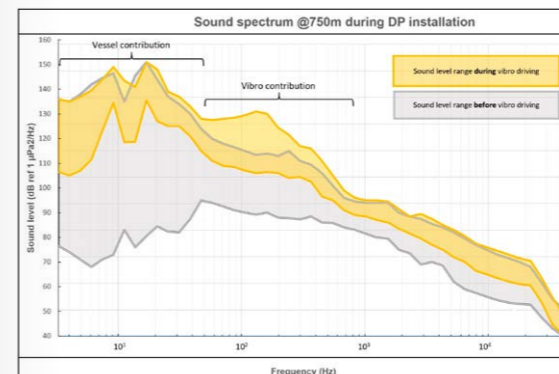
Sound level @750m in sand



Due to the current lack of sufficient feedback from the field there is not much data available, but methods for vibro sound predictions are being developed and joint industry research projects are looking into enhancing the knowledge on this subject.

AIRBORNE NOISE

The substantially lower noise levels during vibro driving compared to impact driving will be confirmed by any offshore worker who has witnessed both. Quite often the power units driving the CAPE VLT is the only real noise that is noticed. There have been offshore wind installation projects already close to shore where limits for airborne noise did not allow impact driving during the night, but vibro driving was allowed and production could continue 24 hours a day.



6.3

ACCURATE

WHEN A PILE IS TRADITIONALLY STABBED INTO A GRIPPER OR INSTALLATION FRAME, IT WILL REST AGAINST THE SIDES OF IT WHEN THE UPENDING/LIFTING TOOL HAS BEEN RELEASED

With a relative high Centre of Gravity there will be an overturning moment which has to be compensated for by the gripper or frame which can be risky, particularly with more challenging sea conditions. Once the impact hammer is placed on top, the centre of gravity is raised even further, increasing the overturning moment.

The CAPE VLT with a pile connected, hanging in the hook of the crane acts like a heavy weight on a piece of string which wants to be vertical by the laws of physics. Apart from not having such horizontal forces acting on the gripper or frame, this phenomenon of wanting to be vertical also means the gripper or installation frame could be eliminated altogether. Various full scale test projects have shown that the verticality can even be corrected at significant penetration depths and that correct-

ing the verticality is quite simple to achieve and control. The latest free hanging offshore monopile installation project achieved a verticality at full penetration of 0.05°.

The orientation of the pile can also be adjusted by manipulating the orientation of the CAPE VLT which can be achieved by tugger lines fixed to the CAPE VLT during driving whilst the soil resistance is at its lowest.

As the rate of penetration can be manipulated by the hook speed, the final height can also be reached with great accuracy. Even if the pile would overshoot its target, it can be retracted to the correct penetration depth. Once the CAPE VLT is turned off, the setup of the soil will return instantly.

INSTALLATION AT DP WITHOUT GRIPPER



WATCH THE CAPE VLT ACCURACY HERE



L-13 INSTALLATION FREE HANGING ON ANCHORS



FOX INSTALLATION FREE HANGING AT DP



6.4

RISK MITIGATION

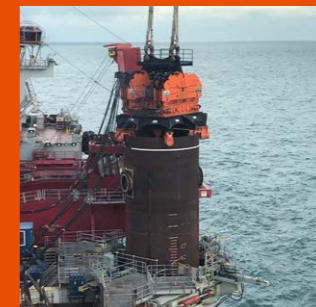
SUDDEN FREE FALL OF PILES DURING IMPACT PILE DRIVING, SO CALLED PILE RUNS OR PILE DROPS, IS AN INCREASING CONCERN IN THE INDUSTRY

The snap loads following pile runs can be very high, exposing both personnel and equipment to high risk. It is very likely that the equipment, or even the crane, will be damaged, which has already happened on several projects. Other risks are that the pile will be out of tolerance once stopped or it may have overshot the required penetration depth or in worst case completely disappear under the seabed. With the hydraulic clamping system the pile is always fixed to the CAPE VLT and held in the crane during driving. Therefore, a drop fall or pile run is eliminated.

As these pile run risks normally happen in layers with very limited resistance, the CAPE VLT may actually help to consolidate the soil with its vibrations by holding it for a period of time after the final penetration has been reached.

The CAPE VLT eliminates the risk over overturing piles as the pile is not released until it is safely driving into the soil to final penetration or to a stable depth before an impact hammer can be safely put on the pile.

WATCH THE RISK OF A RUNNING PILE HERE



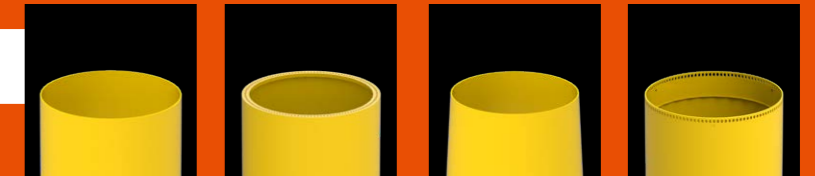
NOT LEAVING PILE DISCONNECTED RESTING IN GRIPPER OF TEMPLATE/JACKET SLEEVE

NO TOOL CHANGE REQUIRED

6.5

FLEXIBLE

**WIDE RANGE
OF PILE
DIMENSIONS
AND TYPES**



GRAUTED CONNECTIONS **FLANGE CONNECTIONS** **SLIP JOINT CONNECTIONS** **C1 CONNECTIONS**

**WITH THE LARGE RANGE OF
CAPE VLT'S AND THE FLEXIBILITY TO
COMBINE MORE UNITS TO CONFIGURE
EVEN LARGE TOOLS**

Pile diameters in the range of 20" to up to over 9m top diameter can be upended, lifted, driven and extracted. With the XXL monopiles being foreseen in the (near) future, work is underway to upgrade the CAPE VLT's to handle piles weighing well over 3,000t

The CAPE VLT-80 and CAPE VLT-160 are particularly suited for the installation of small jacket-, pin- and anchor piles.

The CAPE VLT-320 and CAPE VLT-640 range are mostly used for the

installation of the bigger jacket-, pin- and small monopiles.

The multiple configurations are ideally suited for the larger monopiles up to the XXL monopiles which are foreseen in the next 5 to 10 years.

CAPE Holland has also developed own power units to drive the CAPE VLT. These power units are designed to get the maximum amount of power from a 20ft footprint to reduce the amount of required deck space as much as possible. When

more power is required, more units can be simply added and connected through the CAPE Link System™ which allows all the joined power units to be controlled as one big unit from the control room. In order to save further deck space for the contractor, the power units can be offered as stacked units complete with walkways, guide rails and stair cases. An unique feature of all CAPE Holland built power units is their ability to power the CAPE VLT as well as an impact hammer. Both tools can be connected to the power units and switching from the one to the other is

simply operating some valves and flicking the switch in the software to switch between the tools. This means less deck space required when both tools are used on a project plus the same crew can operate both tools.

Depending on the job, the CAPE VLT's can either be connected to the power units with just hose bundles or with the hose bundles reeled onto the special hose reels. These hose reels can also be stacked to reduce required deck space.



**CAPE
VLT-80**



**CAPE
VLT-160**



**CAPE
VLT-320**



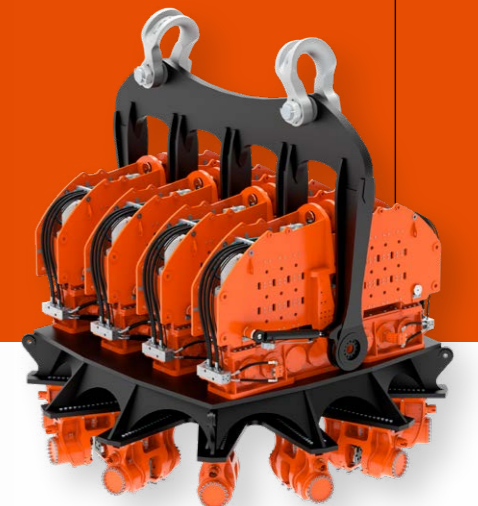
**CAPE
VLT-640**



**TANDEM
CONFIGURATION**



**TRIPLE
CONFIGURATION**



**QUAD
CONFIGURATION**

7.0 THE CAPE HOLLAND ADVANTAGE



**TODAY'S MARKET LEADERS
ARE UNDER INCREASING
PRESSURE TO MANAGE
PROJECTS IN AN EFFICIENT
AND RISK-FREE MANNER**

Although facing numerous complex challenges in achieving this, CAPE Holland helps its customers gain added value from projects by offering expertise, advice and support at every stage. With an unparalleled level of experience and in depth knowledge about the application of the vibro technology in the offshore environment, CAPE Holland can offer support to developers and contractors in the early stages of the tenders to provide input for pile design and installation methodology.

With a very strong and extensive engineering department which houses all disciplines required for developing, designing, building equipment and

supporting projects CAPE Holland can act very quickly on technical challenges. The concept engineers work closely with the R&D team to develop new tools and features which the industry demands. With the inhouse experts on mechanical design, hydraulics, structural, electrical and software engineering working together, a perfect integration of required features can be warranted. The project engineers work together with the project managers, survey engineers and data analysts to prepare and manage the offshore projects.

CAPE Holland offers a total solution in project execution and guarantees

customers 24/7 services worldwide. The equipment is operated and maintained by highly trained operators and technicians to minimise downtime and optimise the use of the equipment. The offshore crew can operate and work on all the CAPE Holland equipment, but is also trained to operate and maintain hydraulic impact hammers which may be used on the same job, reducing crew number on a project.

An important skill to be able to offer the right equipment for a project is the ability to perform driving predictions or driveabilities. CAPE Holland has gained extensive experience in making these predictions in house for a number of

years already and by working closely the geotechnical experts in the field of vibro driving predictions who are also the developers of the software package unique for vibro driving. The feedback from executed projects is used to close the learning loop and to continuously enhance the knowledge and reliability of the driveabilities performed. Based on the soil data and pile design supplied by the client, CAPE Holland runs various driveability calculations in order to select the best CAPE VLT configuration for the project.

DRIVEN
BY
PILES

AT YOUR SERVICE

MARKET
OFFSHORE
RENEWABLES



**SUBJECT
MATTER
EXPERT**

Dick is Business Development Manager, specialising in the CAPE Vibro Lifting Tool for the renewable energy markets, with a Bachelor Degree in Automotive Engineering from HAN Automotive. Commuting between Dwingeloo and Beilen, Dick is responsible for the renewables markets and focuses on making CAPE Holland the global leader in application of the vibro technology in the offshore industry, delivering project specific piling solutions. He believes in

strong customer relationships and beliefs strongly in cooperation between industry players to strengthen the Offshore Renewables Industry.

Dick is personally committed to support the sales department and has been directly involved in several projects like Formosa 1 & 2 OWF's, Kaskasi OWF plus a number of research projects like SJOR, GDP and ZyClAMP.



connect with Dick
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DICK VAN WIJNGAARDEN

**LET'S
MEET**

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