

Technical Noise Mitigation during Offshore-Windfarm Foundation Installation

Examples from Offshore Windfarms:

**Meerwind Süd|Ost, Global Tech I, Nordsee Ost,
DanTysk, EnBW Baltic 2, Borkum Riffgrund 1,
Amrumbank West und Butendiek**

as part of

Offshore Wind R&D Conference 2015

13-14 October 2015

Bremerhaven



**Working Group
Noise Mitigation**

Phases of Noise Mitigation

Duration from preparation to practical implementation of Noise Mitigation System (NMS) can be up to 3 years

Phase 1

Analysis and preparation (up to 1 year)

- Noise emission prognosis and background noise measurement
- Technical analysis of available Noise Mitigation System(s) and decision making with installation companies
- Preparation of Noise Mitigation Concept and approval by BSH (important for finalisation of contracts)

Phase 2

Detailed design, planning, engineering and production (up to 2 years)

- Project-specific engineering, production and preparation of Noise Mitigation System(s)
- Establishing procedures, method-statements and vessel and installation equipment modification if necessary
- Creating noise mitigation implementation plan

Phase 3

Implementation during construction phase

- Marine mammal deterrence procedures
- Use of Noise Mitigation System(s) and if necessary applying maximum hammer energy settings
- Efficiency control of noise reduction and acoustic deterrence success
- Documentation

Noise Mitigation Systems Used (2012 – 2014)

Up to now, there is no state of the art NMS

none tested at all water depths, types of soil conditions and foundations !

Project	No. of Foundation and Ø	NMS: Bubble Curtain										NMS: Others		water depth
		BBC (HTL)	BBC (Wey)	DBBC (HTL)	DBBC (Wey)	DBBC (Wey HTL)	TBBC (HTL)	TBBC (Wey HTL)	SLBC	DLBC	TLBC	IHC (NMS)	HSD	
Meerwind	80 MPs, Ø 5,5m			X										22-26 m
GT 1	80 Tripods, each 3 piles, Ø=2,48 m per pile	X							X	X	X			38 - 40 m
NSO	49 Jackets, each 4 Piles, Ø=2,4 m per pile	X	X						X	X				22 - 25 m
DanTysk	80 MPs, Ø = 6 m	X	X		X	X		X	X					21-32 m
Baltic 2	80 WTG, 39 MPs: Ø = 5,2-6,5 m, 41 JKTs: Ø = 3 m per pile			X			X							MP = 23-35 m, JKT = 35-44 m
Borkum Riffgrund 1	77 MPs, Ø=5,9 m											X		23-28 m
Amrumbank West	30 MPs, Ø = 6 m	from 21. MP			X								from 13. MP	19,5-24 m
	19 MPs, Ø = 6 m	X										X		
	31 MPs, Ø = 6 m	X											X	
Butendiek	80 MPs, Ø = 6-6,5m	X										X		17-22m

Additionally e.g. Small Bubble Curtain (SBC) at Alpha Ventus (2009) and Bard Offshore 1 (3 locations 2010/2011)

Offshore Logistics

Need for several additional vessels: e.g. for efficiency monitoring, for deployment of bubble curtain systems or even a separate vessel for operation of compressors .



Need of additional personnel for the efficiency monitoring: e.g. for online monitoring additional 3 persons.

Modification of the installation vessels: deck layout, capacity of cranes (weight and height), piling frame.

Additional installation vessel: if construction concept needs to be changed into two separate construction steps (e.g. foundation and transition piece).

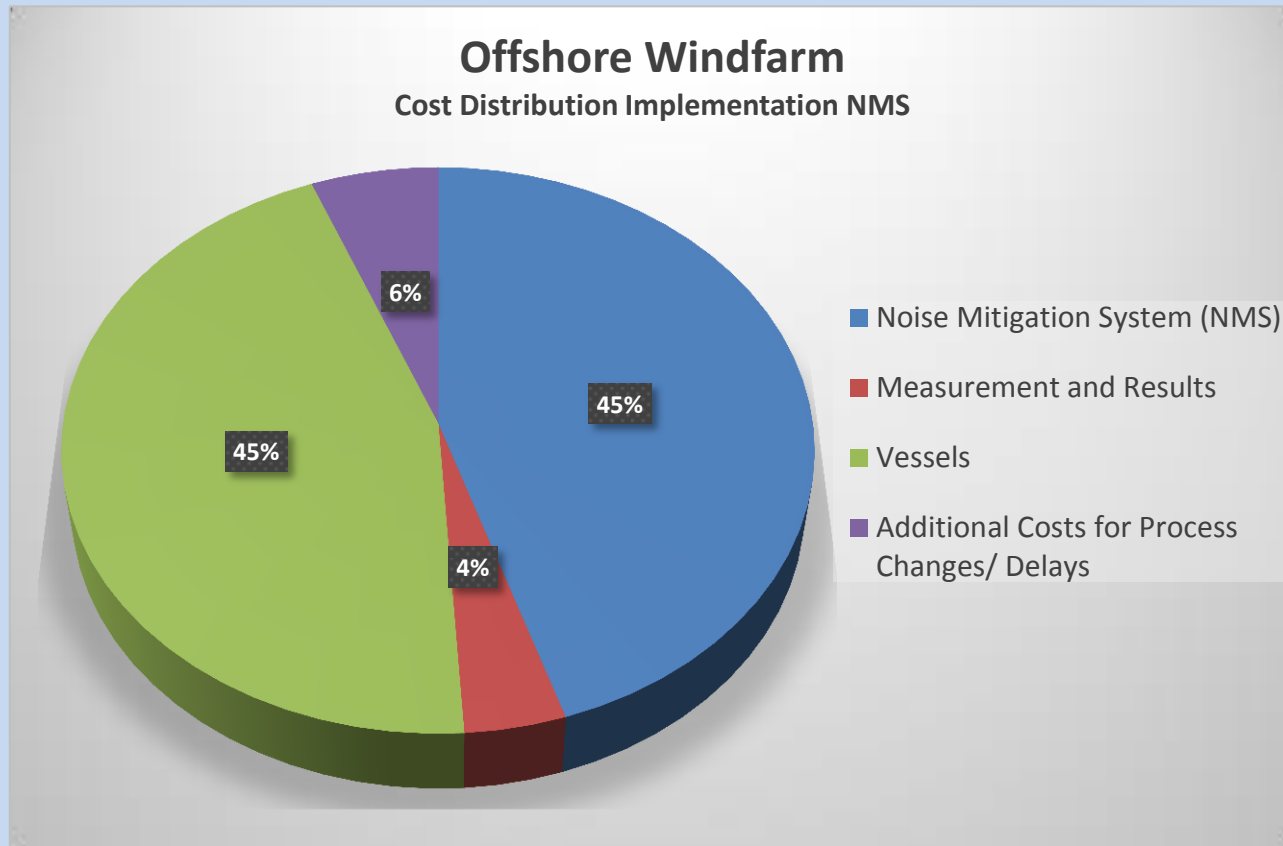
Increased risks: through additional (offshore) activities and more vessel operation

Higher effort in work, time and costs e.g. through **modified/additional engineering, complex workflow procedures** (method statements), requirements of **intensive risk assessment** and increased **marine coordination needs**

Cost Distribution for Implementation of Noise Mitigation Systems

Total costs for noise mitigation systems per project: between 15 and 36 million Euros

Costs for noise protection are around 15% of foundation construction costs



Vessel costs are higher with BBC implementation.

Costs for NMS and additional costs are higher with other alternative NMS.

Deterrence and Efficiency Monitoring

BSH requirement for acoustic deterrence, hydro-sound measurement and harbour porpoise detection (C-PODs) at all locations

Acoustic Deterrence: mostly from the installation vessel or from „Bubble Curtain Vessel“

- 2-3 pingers 40-50 min. before start of piling or operation of NMS
- 1-2 Seal Scarer 30-40 min. before start of piling or operation of NMS (parallel to pinger)



Hydro-sound measurement:

- 1-2 hydrophones at 750m, 1-2 hydrophones at 1500m and increased effort at reference locations (4-6 positions)
- 1-2 hydrophones further field (e.g. at POD station and/or nature conservation areas nearby)
- Furthermore more frequently online hydro-sound monitoring

Harbour porpoise (CPOD) measurement:

- 1-2 mobile PODs at 750m, 1-2 mobile PODs at 1500m,
- 4-5 single POD stations,
- 1-2 PODs further field (e.g. at POD station and/or nature conservation areas nearby)
- Furthermore online POD monitoring conducted



1. Implementation

Installation 80 Monopiles September 2012 to April 2013 using Double Big Bubble Curtain (DBBC)

2. Offshore Logistics

Coordination between installation vessel "Zaratan", bubble curtain vessel "Noortruck" and "Arne Tiselius"

3. Construction Time Impact

Delays of 19.2 days due to DBBC vessel conversion, DBBC breakdowns and from increase in hammering time

4. Costs

Noise mitigation system and vessels: additional costs due to conversions and efficiency monitoring: 15 Mio. EUR

5. Achievements - Challenges

Achievements:

- Noise reduction of approx. 15 dB
- Hammer energy reduction from 2000kJ to 1000kJ

Challenges:

- Implementation of DBBC deployment into the construction process without large time delays
- Ground-coupling
- Weather
- Vessel failure
- Leaks of bubble curtain

1. Implementation

Installation 80 Tripods October 2012 to July 2014 (break between Feb-June 2014) using BBC, SLBC, DLBC and TLBC

2. Offshore Logistics

Coordination between installation vessel and bubble curtain vessel

3. Construction Time Impact

Construction times at some locations prolonged due to BBC operations and reduction of hammer energy

4. Costs

Noise mitigation system and efficiency monitoring: Total costs approx. 17 Mio. €

5. Achievements - Challenges

Achievements:

- Significant improvements of the BBC through use of swivel joints and BBC deployment „under pressure“
- Noise reduction up to approx. 13 dB
- Maximum Hammer energy : 900 - 1200 kJ

Challenges:

- Twisting and wear of und hose-system
- Deployment accuracy at each location at 40 m water depth and in offshore sea-conditions
- Compliance of safety distance between BBC- and Jack-up-Installation- vessel
- Differences in weather restrictions between Installation- and BBC- vessel



1. Implementation

Installation 48 jackets foundations from October 2012 - March 2014. Two different BBC-systems + SLBC or DBLC

2. Offshore Logistics

Numerous BBC configurations -> Multiple changes during installation and at times simultaneous use of two BBC vessels

3. Construction Time Impact

Construction times prolonged by 1-2 hours at some locations due to BBC operations and reduction of hammer energy

4. Costs

Noise Mitigation System, Increased Offshore Logistics and Efficiency Monitoring: Total costs approx. 18 Mio. €

5. Achievements - Challenges

Achievements:

- Improvement of NMS: From 22nd installation 2nd BBC System or combination of systems as well as reduction of hammer energy meant noise limits were complied with at 91% of pile driving events
- Additionally harbour porpoises presence monitored using of real-time online monitoring (WDS)
- Hammer energy: 80% of installations under 1000 kJ and 60% under 900 kJ

Challenges:

- Strong currents at some locations resulted in drifting of bubble curtain
- Compliance with safety distance between BBC and installation vessel



1. Implementation

Installation 80 Monopiles 28.02.13-11.12.13, two different D/BBC-systems , TBBC and SLBC

2. Offshore Logistics

14 different BBC configurations -> vessel change and parallel use of 2 BBC vessels for 60 MPs

3. Construction Time Impact

Through use of NMS construction time prolonged by 1-2 hours at some locations

4. Costs

Noise Mitigation System, Increased Offshore Logistics and Efficiency Monitoring:

Total costs approx. 20 Mio. €

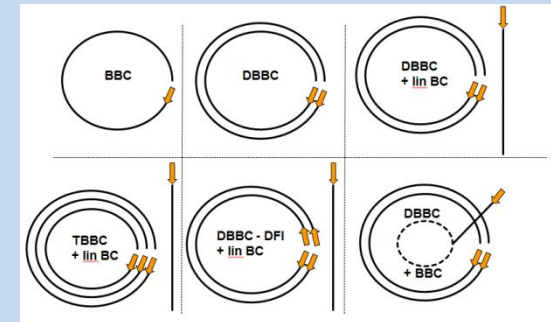
5. Achievements - Challenges

Achievements:

- Improvement of noise mitigation systems: Configuration BBC-HTL plus DBBC-Weyres lead to a maximum noise reduction and compliance of noise limits
- Hammer-energy from 15th Monopile max. 1000 kJ

Challenges:

- HSE Requirements limited possibilities for BBC configurations and an increased process effort and costs.
- Limitation of BBC providers and materials (hose) → Bottlenecks and delays by implementation of BBC configurations.



1. Implementation

Installation 41 jackets 27.08. 2013-11.04.2014 and 39 Monopiles 01.10.-13.12.2013

MP (6 variants): DBBC with 810m-1010m length and spiral-, pretzel-, circular deployment layout, 7-9 compressors

JKT (5 variants): DBBC 1150 m length, 9-12 compressors

2. Offshore Logistics

Different water depths(23-44m) – two foundation types MP and JKT - two parallel offshore installation sites. Rapid installation progress - two vessels for noise mitigation per installation site respectively (1. deploying hoses, 2. operating compressors and further efficiency monitoring.

3. Construction Time Impact Due to difficult soil conditions no clear conclusion possible

4. Costs Noise Mitigation System and Efficiency Monitoring: Total costs not communicated

5. Achievements - Challenges

Achievements:

- Continuous increase of noise reduction through optimisation (5-20 dB);
- No technical failure of noise mitigation systems;
- Coordinated weather limits between the involved installation vessel and NMS vessels;

Challenges:

- Timely implementation of optimisation measures due to speed of installation;
- Timely delivery of measurement results and reports;
- Coordination between the two installation sites regarding acoustic deterrence

Borkum Riffgrund 1



1. Implementation

Installation 77 Monopiles 21.01.2014 – 29.07.2014 with IHC NMS tube

2. Offshore Logistics

Further development of IHC NMS tube for integration into installation procedure and extend functionality

3. Construction Time Impact

Construction times through NMS use, extended hammering time and repair of IHC NMS tube (approx. 10-14 days)

4. Costs

Noise mitigation system and efficiency monitoring: Total costs approx. 20 Mio. €

5. Achievements - Challenges

Achievements:

- Good and constant noise mitigation
- Combination IHC NMS tube and reduced hammer energy <1000kJ (from Pile 15): 97% of noise levels below noise limits
- Noise reduction especially good in the high-frequency range (>20 dB up to 30 dB)
- Reduction of temporal influence through optimised functionality and handling of the NMS as well as good cooperation with installation company.



Challenges during Implementation:

- Technical- / handling- problems of IHC-NMS tube at three locations lead to increased noise emission values
- Compliance of noise limits through IHC-NMS tube only not possible, reduction of hammer energy necessary
- Repeated lost of measurement device through weather conditions and other vessels
- Operating limits for deployment of measurement devices / Installation vessel, measurement device deployment/retrieval not possible in rough weather

1. Implementation

Installation 80 monopiles 14.01.2014 – 18.03.2015, different BBC or DBBC combinations and HSD or IHC NMS tube

2. Offshore Logistics

Split of MP-installation in three phases with different NMS and different installation vessels and NMS vessels

3. Construction Time Impact

The prototype nature of HSD lead to additional handling times of 3-4 h per pile

Restriction of hammer energy → additional 0.5-1 h per pile

4. Costs

Total costs 36 Mio. €; of which 21 Mio. € direct costs (contracts) and approx. 15 Mio. € additional costs through the extension of installation time

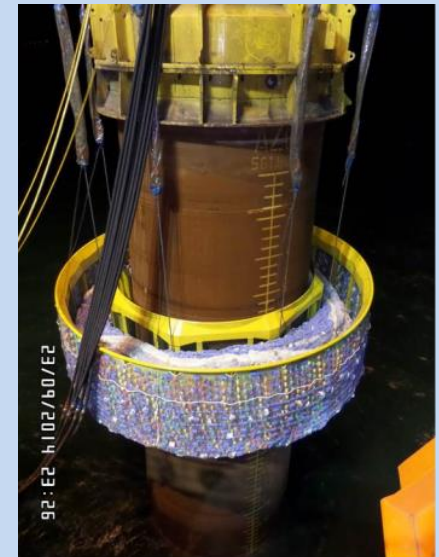
5. Achievements - Challenges

Achievements:

- Improvement of noise mitigation through successive modifications of hose-length
- Deployment radius, maintenance intervals (hole re boring), hose-ballasting
- Improvement of noise mitigation through change/exchange of HSD-net and noise optimised hammer energy control
- Reduction of handling time of HSD through successive improvements

Challenges:

- Breakdown of DBBC vessel and HSD breakdown lead to one week stop in construction
- Weather limits HSD < Weather limits of monopile installation



1. Implementation

Installation 80 Monopiles 31.03.2014 - 22.7.2014 with IHC NMS tube. With BBC from 9th pile

2. Offshore Logistics

Further development of the IHC NMS 6500 during preparatory phase -> necessary modification of Installation process → Separation of MP and TP installation (2 installation units.)

In addition modification of the installation vessel (piling template and crane).

Use of BBC-vessel and further vessel for efficiency monitoring.



3. Construction Time Impact

Through use of NMS construction time prolonged by 1-2 hours at each location plus approx. 14 days due to IHC repair

4. Costs

Noise Mitigation System, Increased Offshore Logistics and Efficiency Monitoring: Total Costs approx. 26.5 Mio. €

5. Achievements - Challenges

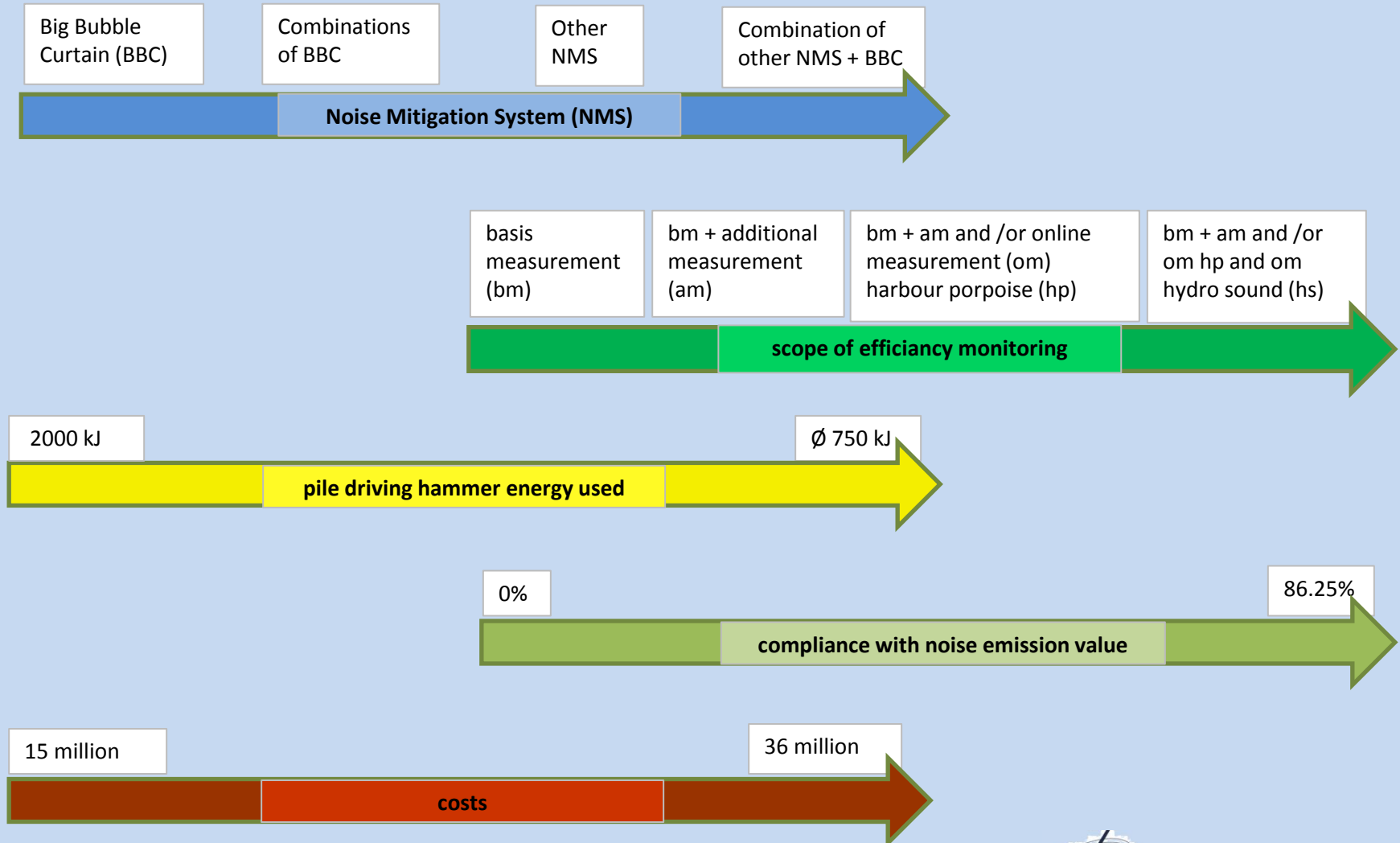
Achievements:

- 69/80 locations below noise limits, overall between 150-167 dB SEL₀₅, noise reduction up to 18 dB
- Hammer energy ≤ 750 kJ
- Good logistics concept of installation company and positive cooperation → temporal impact could be minimised

Challenges:

- Part failure of IHC NMS tube at first location
- Anchor logistics were hampered due to BBC → increased logistic effort and costs of BBC deployment modification
- Speed of MP installation

NMS Development of the eight German projects from 2011-2014



Summary

The results and developments described show the strong commitment of the industry.

Noise emission limits were often achieved following adjustments to the noise mitigation systems and were sometimes even well below.

The different projects are however still limited in comparability due to:

- Different water depths
- Different soil conditions
- Different current and weather conditions
- Different foundations
- Different pile-diameter and length
- Different hammer
- Different vessels
- Different installation tools (e.g. piling-templates, gripper)



There is therefore no general state of the art noise mitigation system standard available yet, with a NMS needing to be developed, tested and adjusted specifically for each project



Thank you for your attention!

**On behalf of the OFW working group noise mitigation
(AK Schallschutz)**

Dr. Susanne Schorcht

Permit Manager Offshore
wpd offshore solutions GmbH
Stephanitorsbollwerk 3 (Haus LUV)
28217 Bremen

T +49 (421) 16866-5815

M +49 (160) 8954543

F +49 (421) 16866-5999

s.schorcht@wpd.de

<http://www.wpd-offshore-solutions.de>

Appendix: List of Abbreviations

BBC:	Big Bubble Curtain
CTD-Sonde:	Conductivity, Temperature and Depth
DBBC:	Double Big Bubble Curtain
DLBC:	Double Length Bubble Curtain
HSD:	Hydrosound Damper
HTL:	Hydrotechnik Lübeck (BBC system supplier)
IHC:	IHC Merwede B.V. (producer of IHC tube)
JKT:	Jacket
MP:	Monopile
NMS:	Noise Mitigation System
TBBC:	Triple Big Bubble Curtain
OSS:	Offshore Substructure (platform)
C-POD:	Continuous Porpoise Detector
Ref.:	Reference
SLBC:	Single Length Bubble Curtain
TLBC:	Triple Length Bubble Curtain
WTG:	Wind turbine generator
Wey:	Weyres-Offshore (BBC system supplier)
WDS:	Wireless Detection System