Modeling, Testing and Measuring Underwater Sound from Seismic
Seismic surveys...

Sound...or...

...noise...?
Sound – Some definitions

Sound Pressure Level SPL
(of sound, at given location for a given time interval T)

\[ SPL_{shot} = 10 \log_{10} \frac{1}{T} \int_0^T \frac{p^2(t)}{p^2_{ref}} \, dt \] [dB re 1 \mu Pa^2]

\( p_{ref} \) is the reference pressure (taken equal to 1 \mu Pa for water)

Sound Exposure Level SEL
(of sound, at given location for a given time interval T)

\[ SEL_{shot} = 10 \log_{10} \frac{1}{T_0} \int_0^T \frac{p^2(t)}{p^2_{ref}} \, dt \] [dB re 1 \mu Pa^2s]

\( p_{ref} \) is the reference pressure (taken equal to 1 \mu Pa for water)
and \( T_0 \) is the reference time of 1 second

Peak-to-Peak Pressure level Lpp
(of sound, at given location for a given time interval T)

\[ L_{pp.net} = 20 \log_{10} (\max(p(t)) - \min(p(t))) \] [dB re 1 \mu Pa^2]
Wintershall and partner group face stringent underwater sound level restrictions that prevent seismic acquisition in their German H&L blocks:

- < 160 dB Sound Exposure Level (SEL) or 190 dB peak-to-peak at a radius of 750 meter from the source.
- Mammals may not be chased away from more than 10% of the Flora and Fauna Habitat. Sound disturbance effects will be felt up to 138 dB.
Modelling Compared to Measurements

- During the Angelina survey (2007) underwater sound from the seismic source was recorded at 500 m, 1500 m and 2500 m.
- Below the measurements are compared to TNO modelling of the same source.
NAM, Sterling Resources and Hansa Hydrocarbons acquired seismic in 2014; part of the permitting conditions was to acquire underwater sound measurements during a seismic acquisition.

ENGIE, Hansa Hydrocarbons and Wintershall contributed to the underwater sound measurements as German H&L partner group.

Acknowledgements:

- ENGIE
- Hansa Hydrocarbons
- NAM
- Sterling Resources
Objectives of the Underwater Sound Measurements

- In summer 2014 Hansa acquired 3D seismic on the Dutch side, adjacent to the German H&L blocks.

- Objectives:
  - **Alternative Source Test Line**: Test different source designs with reduced sound level.
  - **Sound measurements**: Support calibration of sound propagation modelling for different source designs.

- Measurements and modelling performed by Arcadis, Deep & TNO.
Seismic Source Designs

**M1 Test – 1 Production Source**
3147 cu.in, 3 sub-arrays, **2000 psi**, dual sources (M1)

**M2 Test – 3 Alternative Sources**
- 1695 cu.in, **2000 psi**, 1 sub-array, dual sources (M2T2)
- 1049 cu.in, **2000 psi**, 2 sub-arrays, single source (M2T1)
- 1049 cu.in, **1000 psi**, 2 sub-arrays, single source (M2T3)

M1 Test
Reconfiguration at end of 4Quads Survey

M2
Hydrophone Set-up (1)
1 dynamic hydrophone connected to boat around 10 km to 15 km from seismic line and aligned with other hydrophones

Hydro 1
Hydro 2
Hydro 3

3 static hydrophones

Hydro 5
Note: Hydro 4 is spare

Acoustic release hydrophone

Legend
- Recorders
- DeploymentAreas
- M2Box_Coordinates
- M2Measurement_Box
- PreferredMeasurementLine
- AMI_LineCrossing
- Offset_+130m_1376
- 1376

3 static hydrophones
SEL Measurement during M1

Map shows:

- 2-week coverage of continuous SEL measurements at hydrophone 1 during production seismic survey with M1 (biggest) source
- Variation of SEL with angle bearing and distance
M1 Sound Measurements vs Distance

- To avoid directivity influence, only data with angles +/- 5 degrees are considered.
- Measurements taken from the hydrophone receivers 1, 2 & 3 are plotted against distance.
Sound Measurements – Time Series

M1 source (biggest)
3147 cu.in. – 2000 psi

M2T3 source (smallest)
1049 cu.in. – 1000 psi
M1 SEL Sound Measurements vs Modeling

M1 source (biggest)
3147 cu.in. – 2000 psi
Recorded at hydrophone 1
M2T3 SEL Sound Measurements vs Modeling

Track of Seismic Vessel

M2T3 source (smallest)
1049 cu.in. – 1000 psi
Recorded at hydrophone 1
Sound measurements vs Modeling

M1 source (biggest)
3147 cu.in. – 2000 psi

M2T3 source (smallest)
1049 cu.in. – 1000 psi
SEL vs Frequency

M1 Source (3147 cu.in, 2000 psi) at hydrophone 1

90% of SEL energy between green lines

CPA 28min after start of line
Conclusions

- Complex project with many stakeholders
- Carefully consider HSE and safety
- SEL and peak-to-peak SPL (Lpp) significantly decrease with lower source energies
- Modeling overestimated sound attenuation at far range: this remains unexplained
  - Are acquisition conditions (very quiet/flat sea, very reflective) the reasons for lack of far range attenuation?
  - More efforts on the TNO modelling are required
“The Effects of Noise on Aquatic Life”, Dublin, Ireland 10-16 July 2016, an abstract on the 4Quads underwater sound measurements & modelling will be submitted by TNO:

Sound Exposure Level Measurements and Model Predictions for a Marine-Seismic Airgun Array in a Shallow-water Environment.

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Airgun Modelling Workshop organized on Saturday, 16 July 2016, by Michael Ainslie, TNO
Alternatives

- Marine vibroseis

- eSource Schlumberger

- Incoherent shooting of conventional airguns and deblending during processing
Questions?