With air bubbles against World War II mines: Challenging Detonation Tests in the Baltic Sea

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In the years after 1945 many thousands tons of ammunition were sunk into the Baltic Sea, including areas near the coast. They still pose a threat, in particular to maritime traffic. Such huge amounts of explosives cannot be salvaged but have to be destroyed in controlled explosions. Detonation of several hundred kilograms of explosives under water generates shock waves that can be life-threatening to humans and animals. Primarily marine mammals are extremely endangered. Against this background, researchers from Kiel [1] have investigated, if and to which extend underwater pressure waves caused by detonations can be damped using artificially established air bubble curtains.

WTD 71 – "Technical Center for Ships and Naval Weapons, Marine Technology and Research" in Eckernförde at the Baltic Sea is one of ten Technical and Research Centres of the German Federal Armed Forces (Bundeswehr). It covers the full range of naval defence technology in all phases of development and testing. The Research Department for Underwater Acoustics and Marine Geophysics in Kiel investigates amongst others the attenuating effect of bubble curtains on explosion shock waves with the aim to dispose ammunition legacy from World War II as environmentally acceptable as possible. The studies are performed in cooperation with the State Office for Civil Protection and Disaster Control in Schleswig-Holstein – the authority responsible for disposal of unexploded ordnance.

For this purpose, experts from the WTD 71, assisted by Hydrotechnik, a Lübeck company, performed detonation tests where perforated circular pipes are placed on the seafloor to establish a bubble curtain around the explosion location. While the first series of experiments (pictures 1 and 2) used three concentric pipes, later series were restricted to a single circular pipe with a total air flow of 40 cubic meters per minute.

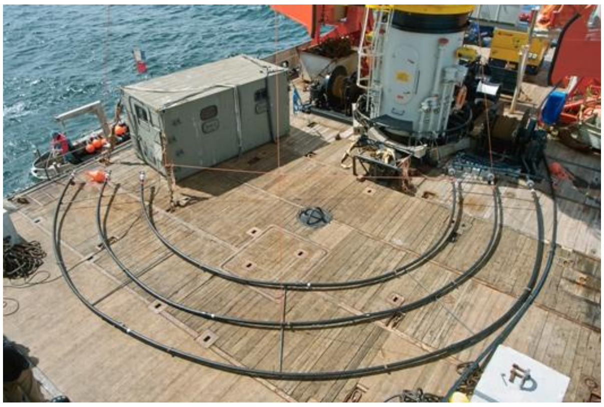

Figure 1: Mounting the pipes that will produce the air bubble curtain [2].

A ship anchored at a safe distance is used as measuring platform. From there six hydrophones are positioned by deck crane in four different depths for sound level measurements. The on-board measurement system pre-amplifies the sound signals and passes them through a 50Hz high-pass filter before they are recorded on a transient recorder for subsequent evaluation.

Figure 2: Test detonation with lower explosive charge. In the foreground the CompAir compressor that generates compressed air to produce the bubble curtain [2].

For special tests series like this the research team needs advanced measurement systems. Transient recorders series LTT-184 (figure 3) und LTT-186 live up to the high demands on safety and ruggedness. These front-ends, developed and produced by Messtechnik LTT Labortechnik Tasler, a specialist in ultra-fast measurement technology based in Würzburg, extend the scope of conventional PC measurement technology to dimensions never reached before. The maximum sample rates per channel vary − dependent on the resolution required − between 2.5 MHz for 16 Bit and up to 20 MHz for 12 Bit. A single recorder provides up to 16 differential inputs. Cascading allows many more parallel channels to be captured synchronously.

Separate A/D converters and amplifiers for each input channel allow simultaneous sampling on all channels and channel-specific amplification with input ranges from ± 1 Volt to ± 50 Volt (optional: ± 10 to ± 200V). Each input is equipped with an adaptive anti-aliasing filter. To facilitate future measurements even more, LTT offers the new general-purpose measuring amplifier LTT-500. It can supply up to 8 sonar sensors with 20 Volts (or 30mA). Combined with transient recorders LTT-184/186, sensor signals with a bandwidth of 1MHz can be amplified up to 1660 times.

The transient recorder is connected to the PC via SCSI, USB or Ethernet – or for larger distances via fibre optic cables. Thus, the signals can be remotely displayed and monitored on the connected PC. The LTTview software considerably facilitates the acquisition, playback and analysis of the measured data. A comprehensive trigger function determines the start of the data acquisition. Online maths operations allow a first evaluation of the measurement while it is running. The measured data are stored directly in file formats like Famos, Diadem or National Instruments TDM allowing straightforward post-processing.

To make absolutely sure that no data get lost, they are firstly stored in the instrument – either in a high-speed RAM with up to 512 Megabytes or on a built-in, shock-safe hard disk with up to 40 Gigabytes memory depth. This ensures that the results are safely recorded, even in most challenging operating environments and in the worst case – failure of the PC connection.

Figure 3: The rugged transient recorder series LTT-184 and LTT-186 have delivered high performance under harsh conditions including detonation tests on shore and on sea.

Figure 4 shows a typical pressure-time signal from the detonation of a mine charged with 300 kg at a distance of about 800 meters. Very high sample rates of up to 2.5 Megasamples per second and channel are required to ensure the necessary signal bandwidth for evaluating the short pressure peaks typical for detonations and analysing the attenuation effect up to the 100 kHz range.

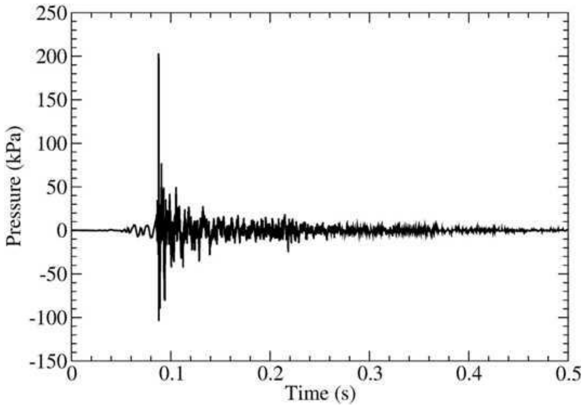

Figure 4: Pressure-time signal after detonation of a mine with a charge of 300 kg at a distance of 800 meters [1].

In particular the porpoises, whose population in the Southern Baltic Sea is critically endangered, react very sensibly on this frequency range. They use – as their relatives the dolphins – an ultrasound localisation system that functions similar to the sonar system known from submarines.

Figure 5 shows the one-third octave spectra for an undamped explosion and for two explosions with air bubble curtain. These first results show no significant attenuation in the frequency range below 1 kHz while there is an attenuation of about 4 dB in the range above 1 kHz.

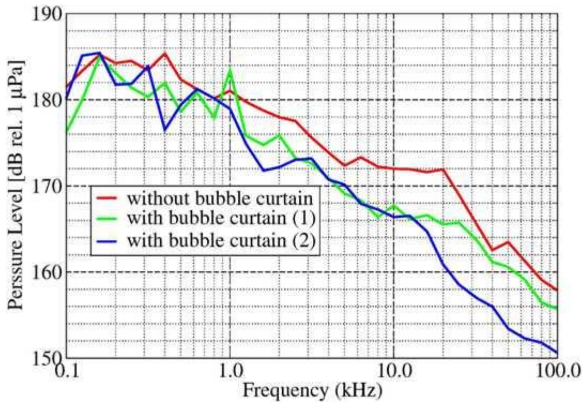

Figure 5: One-third octave spectra of measured data with and without an air bubble curtain (integration time 1 sec) [1].

This is lesser attenuation than expected based on other experiments. The reason seems to be that large explosive charges emit hot explosion gases that produce a considerable flow of displaced water which of course will affect the pressure propagation. Further experiments will focus on different bubble curtain diameters.

Pictures:

Figure 1: Mounting the pipes that will produce the air bubble curtain [2].

Figure 2: Test detonation with lower explosive charge. In the foreground the CompAir compressor that generates compressed air to produce the bubble curtain [2].

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References:

[1] E. Schmidtke, B. Nützel and S. Ludwig: “Risk mitigation for sea mammals - The use of air bubbles against shock waves”, Proceedings of the International Conference on Acoustics “NAG/DAGA 2009”, Rotterdam, 2009, pp. 269-270

[2] Figures 1 and 2 by courtesy of CompAir Drucklufttechnik GmbH, Simmern.

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