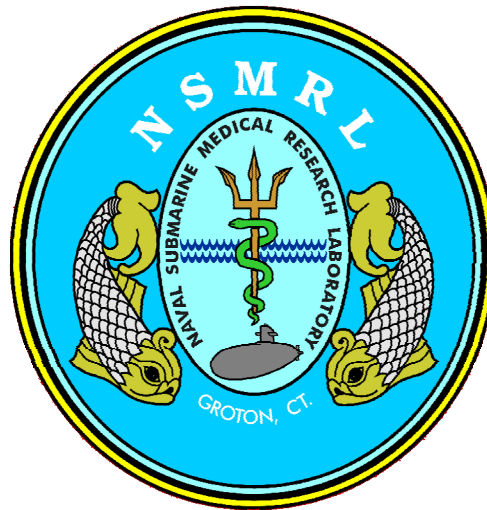


Naval Submarine Medical Research Laboratory

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Test Report and Guidance for Caviblaster

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BACKGROUND

Naval Sea Systems Command (05) requested an evaluation of the Cavidyne Caviblaster (Model LG-1620) for possible consideration for the Approved for Navy Use (ANU) list. The system consists of a compressor and a wand. The compressor provided high pressure air to the wand. The nozzle of the wand was pointed at the designated target and activated via a hand trigger. The wand was designed such that cavitation was produced in the water at the end of the wand, and this cavitation was used to clean the target. The cavitation also produced considerable noise. Prior to being added to the list, a safety evaluation regarding the noise levels produced by the tool was conducted and guidance generated so that Navy divers would be able to use the tool safely.

OBJECTIVE

There were three objectives for this test of the Cavidyne Caviblaster (Model LG-1620). The first objective was to collect acoustic output data for the wand while the system was activated under conditions similar to working conditions. The second objective was to collect in-air acoustic data associated with the compressor unit during normal operation. The final objective was to analyze the acoustic data to determine safe sound exposure limits for the system under test.

APPROACH

The general approach was for a diver to use the test system on a steel plate in configurations and at approach angles similar to normal use. While the system was activated, the acoustic output of the system was measured.

The system was set up at the Naval Undersea Warfare Center's Dodge Pond Acoustic Measurement Facility by Cavidyne LLC and tested to insure that the operation of the system was within specifications. A .25 inch steel plate (3 feet x 3 feet) was lowered into the water in the center well of the Dodge Pond test facility to test depth. Test depths were 15 and 30 feet. Most of the measurements were made at 15 feet with a limited set of measurements at 30 feet.

A diver using standard U.S. Navy scuba diving gear and a full wet suit including hood was lowered to the test depth. All diving procedures were in accordance with the U.S. Navy Diving Manual, Revision 6. The stabilization for the diver was a tending line attached to a clamp. The test plate was tended, but not rigidly stabilized. The cleaning wand for the Caviblaster system was at the test area, and the diver took the wand after he was in position. After the diver notified topside that he was ready to test and the start test was confirmed, the diver placed the wand in the specified orientation (20, 45, or 90 degrees relative to the plane of the test plane), aimed at a test spot marked on the test plate. The diver's chest was parallel to the steel plate. The Caviblaster was activated by the diver for a 5 second burst.

The test area was instrumented with an underwater measurement system for the acoustic measurements at the diver. Hydrophones were at two locations: (1) near the diver's head on the side closest to the test plate and (2) a location 1 meter from the diver and the test spot on the test plate. The hydrophone away from the diver was affixed to the plate via an extension so that it was always a fixed distance from the test spot. In addition, a Bruel & Kjaer sound level meter was used to measure the sound level at the topside compressor for the system.

Five divers used the system, using a minimum of two orientations and five repeat measurements for each orientation, yielding five sets of underwater acoustic measurements, one set per diver. The topside sound level measurements were done twice. These measurements provided an estimate of the variability due to the user as well as capture variability in the noise generated by the system.

The measurements were conducted over a three-day period. The first day was for set-up and verification of the operation for the test system as well as the underwater acoustic measurement hardware. The divers examined the test position under water and confirmed acceptance of the test set-up. The acoustic measurement system was set up and calibrated. The second day was devoted to acoustic measurements. All measurements were conducted within a single day. The third day was for backup and review to insure that any missing data points were filled in and any supplemental measurements were taken. The latter part of the day was for breakdown and cleanup.

RESULTS

The Caviblaster data is presented in two parts. The first part is the underwater noise due to the cavitation at the wand. The second part is the in-air measurements taken of the topside unit of the system.

In Water:

The data for the two hydrophones consistently showed lower levels for the hydrophone attached to the plate. However, the hydrophone next to the diver was more variable. Upon further analysis, it was noted that the maximum values for the "plate" hydrophone matched those of the mean values measured at the diver so it was decided to use the maximum values for the "plate" hydrophone to calculate the permissible exposure limits (PELs). The in-water values for the 15-foot test depth are shown in Figure 1 on the next page.

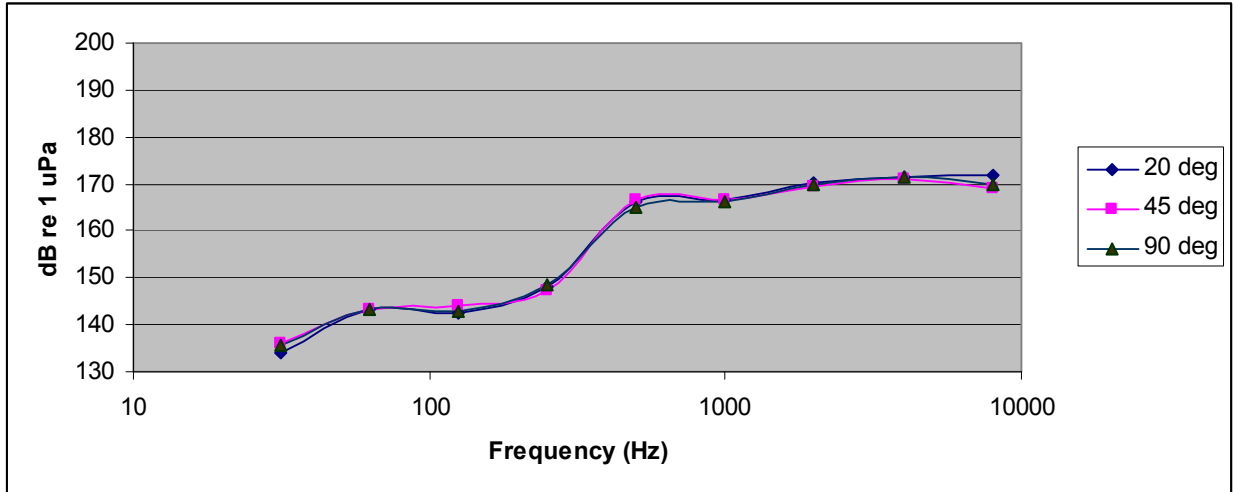


Figure 1. The in-water dB SPL for the Caviblaster measured at octave band frequencies from 31.5 to 8000 Hz. All data shown was for 15-foot test depth. The parameter is the angle of incidence for the Caviblaster.

The data show that the energy slowly rises as frequency increases, up to 500 Hz. Above this frequency, the output was constant. Furthermore, the angle of incidence did not have an impact on the output.

Two divers used the gun at the 30-foot test depth. There were only two angles of incidence at this depth because of the findings at 15 feet. The data for the 30-foot test depth are shown in Figure 2. The data are plotted for the maximum level at “plate” hydrophone, just as for the 15-foot test depth.

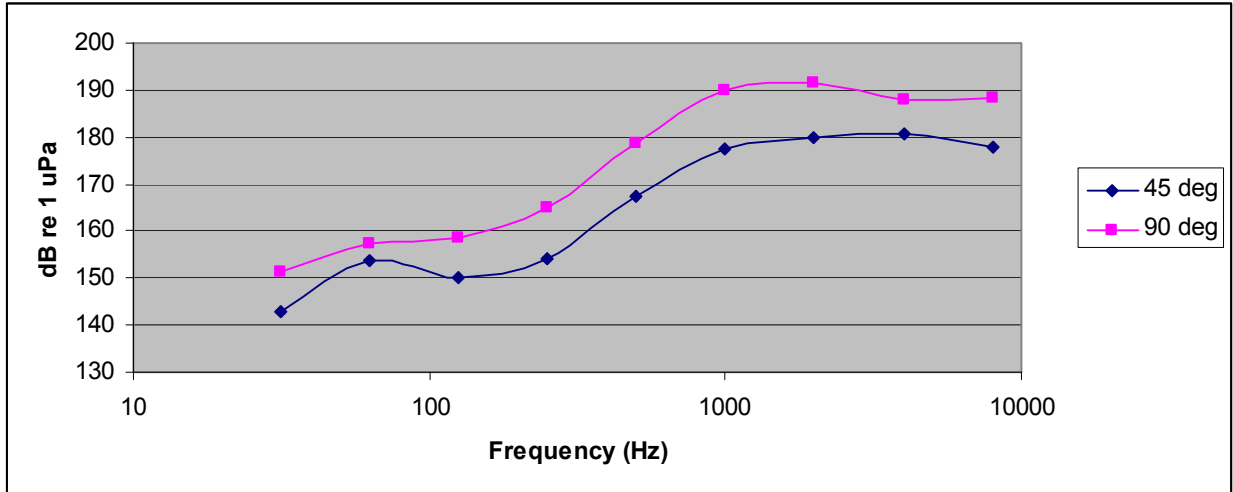


Figure 2. The in-water dB SPL for the Caviblaster measured at octave band frequencies from 31.5 to 8000 Hz. All data shown was for 30-foot test depth. The parameter is the angle of incidence for the Caviblaster.

The data at the 30-foot test depth show the same general trend across frequency but differ in two ways from the 15-foot test depth. First, the SPL at 30 feet is up to 10 dB higher. Second, the angle of incidence at 30 feet made a significant difference in the level of the signal. Discussions with the manufacturer and users of the system indicated that the 45-degree incidence was most representative of the way the system would be used, so the data from this angle were used for the PEL calculations at 30 feet.

In Air:

The in-air noise levels were measured at a 1-meter distance from the center of the topside unit around the compressor assembly at three positions: (1) next to the engine, (2) next to the pump, (3) and to one side. The noise levels varied by position with the highest level near the engine: 107 dB(A). The levels were equal at the other two positions at 103.5 dB(A).

ANALYSIS – PERMISSIBLE EXPOSURE LIMITS (PELs)

The acoustic data was used to calculate PELs for three types of diver dress: (1) helmeted (Mark 21), (2) wet suit hooded, and (3) unhooded. For purposes of the guidance, a dry suit hooded diver was covered by the wet suit hooded diver guidance. The helmeted guidance required conversion of the data into a form suitable for in-air exposure, whereas the hooded and unhooded guidance used the in-water SPLs directly. The derivations for the three diver dress conditions are described in Wolgemuth, et al, 2008. Derivation of PEL for the in-air exposure is based on OPNAVINST 5100.23G.

In-Water PELs:

Typically, guidance is provided based on the maximum output of a system. Based upon the frequency characteristic shown above, namely, most of the energy in the signal is above 500 Hz, the greatest risk from this system is hearing damage. In order to estimate the impact on hearing for a system like the Caviblaster, which varies in level over time, the best estimate of the impact on diver hearing will come from the mean, provided that the maximum deviation over time is sufficiently small. The mean, minimum, and maximum levels were determined along with the standard deviation to measure how well the mean was representative of the noise level. As expected, the variance increases (standard deviations > 5 dB for at least 3 frequencies) and the difference between minimum and maximum increases as frequency increases (> 15 dB at 4 frequencies). These factors suggested that the PEL should be more conservative than the mean. PELs were calculated for the mean, maximum, and minimum for three modes of diver dress: (1) unhooded, (2) hooded, and (3) helmeted (MK21). The PELs below are shown for the mean noise level and maximum noise levels to show the range of PELs. The midpoint between the mean and maximum levels was used as the PEL. They are presented by diver dress.

1. Unhooded (Bareheaded): 21 minutes for the mean noise level; 4 minutes for the maximum noise level. Recommendation: Do not use this system unhooded.
2. Hooded: 202 minutes for the mean noise level; 42 minutes for the maximum noise level. Recommended PEL – 101 minutes continuous; duty cycle adjustment permitted.
3. Helmeted (MK21): 58 minutes for the mean noise level; 11 minutes for the maximum noise level. Recommended PEL – 26 minutes continuous; duty cycle adjustment permitted.

Duty cycle adjustment permitted – The PEL can be increased if the percent of time on is reduced from 100%. The formula is – Adjusted PEL = PEL * ((time off+time on)/time on). In order for this formula to be applied, the duty cycle must be regular, that is, the time on must be evenly spaced throughout the total time period.

In-Air PELs:

All of the noise levels impose severe limits on exposure per 8-hour day per OPNAVINST 5100.23G. In fact, exposure to the levels of 107 dB(A) or 103.5 dB(A) are not permitted without hearing protection. The PEL with hearing protection would depend on the noise reduction rating of the hearing protector.

DISCUSSION AND CONCLUSIONS

While the PELs seem short, a comment made by one of the diver users that this was one of the loudest tools he had ever experienced in over 30 years of diving suggests that the PELs are not so surprising. All divers spontaneously commented that the system was very loud. As a normal precaution, audiograms were done for the diver users for this test and none showed any threshold shifts.

All tests were conducted successfully. The Cavidyne system performed without any failures, and acoustic data was collected at two depths. The acoustic output and PELs derived from the system indicate that it is comparable to the unmodified zero-thrust Hydroblaster tested in 1996.

The Navy Experimental Diving Unit and Carderock Division did an extensive series of acoustic measurements on that system and the results for the hydroblaster (Kirkland and Gullings, 1996) are similar to those reported here for the Caviblaster. Both the output levels and frequency distribution are slightly higher for the Caviblaster than for the hydroblaster at 500 Hz and above. The PEL for the “unsilenced” hydroblaster was one hour for a helmeted diver, which is longer than the PEL for the helmeted diver with the Caviblaster. It should be noted that the PEL was calculated as very near the point beyond which Temporary Threshold Shift (TTS) would be expected and at which tinnitus for some divers could be expected. PELs were not calculated for the unhooded or hooded diver for the hydroblaster. The criteria for PELs used in the analysis with this unit are more conservative and avoid the possibility of TTS.

This is a very high acoustic output tool. The PELs are correspondingly short. The easiest way to get full operational use of the system is to have divers share the use of the system during an operation and use it in a non-continuous fashion. The latter strategy was employed for cutting armor belts on the USS Monitor with the hydroblaster and was operationally very successful. Hooded divers with a full facemask would be the best protected and have the most time available. It is not recommended to use this system with bareheaded divers.

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Kirkland, P.C. and Gullings, L.F. (1996). A review of two reports dealing with acoustic evaluation of a zero-thrust hydroblaster when using the MK 21 Mod 1 diving helmet. Report to NAVSEA OOC57.

Wolgemuth, K.; Cudahy, E.; and Schwaller, D. (2008). “Underwater and Diver Station Work-Site Noise Surveys”, NSMRL/50204/TR-2008-1255.

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