

Use of a High-Energy and Low-Pressure Energetic Source for Mine and Obstacle Clearing

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LONG TERM GOALS

Past numerical and experimental work suggest that energetic charges that produce a low-level long-duration pressure pulse would enhance the damage to certain types of underwater structures, generate larger craters, generate larger volume bubbles, and generate larger water plumes than conventional high pressure explosives. SRI International has conceived a novel high-energy low-pressure (HELP) energetic source that has the potential to compliment the existing conventional and advanced high-pressure energetic charges used by the Navy. The HELP charge is not viewed as an explosive that will generally outperform other explosives, but rather an explosive for neutralizing targets that are particularly sensitive to low pressure long duration loads.

APPROACH

The HELP charge concept consists of an energetic source that generates an initial pressure spike through detonation of a small portion of the material followed by a low-pressure long duration pressure pulse due to rapid deflagration of the remaining material. This concept originated from experiments performed with SRI's patented dilute explosive tile (DET), which consists of PETN uniformly mixed with polystyrene beads. DET can be tailored to produce peak detonation pressures on the order of 3 to 50 kbar and detonation velocities approximately half of conventional explosives. In tests performed with DET, it was observed that a significant amount of unreacted carbon residue remains after the detonation. The HELP charge concept entails adding an oxidizer to the DET matrix to produce rapid combustion of the unused carbon. This rapid combustion is expected to produce a low-pressure load (a few hundred psi) for a long duration (10 to 100 ms). The long duration results from a deflagration velocity of hundreds of m/s as compared to 5000 to 8000 m/s for conventional explosives.

The overall program approach consisted of first performing analysis to estimate the possible HELP charge performance followed by experiments to confirm the HELP charge performance. The analytical effort, which was completed in FY97, consisted of performing TIGER calculations to design a HELP charge mixture, performing one-dimensional hydrocode calculations to estimate HELP load levels, and performing two-dimensional hydrocode calculations to estimate the HELP charge lethal footprint for neutralizing SZ mines and obstacles. The primary conclusions from the analytical effort was that the HELP charge may produce a 35% increase in the lethal footprint for neutralizing Target E tilt rod SZ mines and SZ obstacles as compared to a M58 line charge with C4 explosive.

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The experimental effort, which is currently underway, consists of characterizing the HELP charge detonation velocity, constant volume pressure, underwater shock pressure-time history, and effects against a Type E tilt rod SZ mine. The experimental work, which has been completed, is summarized below.

WORK COMPLETED

The detonation wave speed in HELP charges was measured using ionization time-of-arrival (TOA) pins. Experiments were performed with uniform mixtures of PETN, polystyrene beads, and ammonium perchlorate (AP) as well as with uniform mixtures of polystyrene beads and AP, which were detonated on an outside surface using Detasheet.

To characterize the HELP constant volume pressure, nominal 185 gm mixtures of PETN, polystyrene beads, and AP were detonated within a constant volume chamber. In these experiments the relative quantities of PETN, polystyrene beads, and AP were varied to determine the optimum mixture. In addition, an experiment using C4 was performed for comparison with the HELP charge results.

Using SRI's water shock pool facility, experiments were performed to determine the HELP charge pressure-time history. Pressure measurements were made at standoff ranges from the charge of 30.5 cm (12 in) to 243.8 cm (96 in) to study the attenuation characteristics of the pressure waveform generated by the HELP charge.

RESULTS

Two detonation velocity experiments were performed with 50% and 80% HELP charges consisting of 5.08 cm (2.0 in.) in diameter by 15.24 cm (6.0 in.) long.

- The 50% HELP charge was comprised of 92.67 g of PETN, 46.33 g of AP, and 46.33 g of foam beads.
- The 80% HELP charge was comprised 92.67 g of PETN, 74.13 g of AP, and 18.53 g of foam beads.
- The average velocity over the 15.24 cm charge length was 3700 m/s and 3850 m/s for the 50% and 80% HELP charges, respectively.
- The measured decrease in the detonation velocity between the detonation point and the end of the charge was less than 10%.
- The detonation velocity for a DET charge comprised of 92.67 g of PETN and 92.67 g of foam beads is approximately 3000 m/s; Detonation velocity for C4 explosive is approximately 8000 m/s.

Thus, the experimental results suggest that the addition of AP may have increased the detonation velocity by approximately 25% as compared to a DET charge.

To investigate HELP mixtures that would produce detonation velocities lower than DET, experiments were performed with HELP charges consisting of a uniform mixture of AP and polystyrene beads. These charges were detonated at one end using Detasheet. The charges were 10.16 cm (4.0 in) in diameter (found to be the critical diameter) by 10.16 cm (4.0 in) long. For a 80% HELP charge the measured detonation velocity was 1500 m/s, which is 50% lower than the detonation velocity for DET.

Table 1 summarizes the constant volume experimental results. The last column in Table 1 gives the residual material that was in the chamber after the experiment. This material is an indication of the charge efficiency in performing gas work through oxidation of the carbon in the HELP source matrix. For example, less material remaining in the chamber after the test indicates a more efficient HELP charge. The final chamber pressure from the 80% HELP, 260% HELP, and PETN /AP charges is similar to the C4 charge. This indicates similar mass specific energies. However, from the pressure-time history buildup to the final constant volume pressure we were unable to determine the level of late time pressure produced by the HELP charge.

| Test No. | Charge Type | Charge Properties (g) | | | Constant Volume Properties | |
|----------|-------------|-----------------------|------------|--------|----------------------------|------------------------|
| | | PETN | Foam Beads | AP | Pressure (psi) | Residual Material* (%) |
| 1 | DET | 92.67 | 92.67 | - | 325 | 25 |
| 2 | 50% HELP | 92.67 | 46.33 | 46.33 | 650 | 15 |
| 3 | 80% HELP | 92.67 | 18.54 | 74.13 | 760 | 13 |
| 4 | 200% HELP | 46.33 | 46.33 | 92.67 | 575 | 25 |
| 5 | 260% HELP | 46.33 | 18.54 | 120.46 | 760 | 11 |
| 6 | 80% HELP | 92.67 | 18.54 | 74.13 | 720 | 15 |
| 7 | PETN & AP | 92.67 | | 74.13 | 750 | 15 |
| 8 | C4 | 185.33 | | | 780 | 0 |

Table 1. Summary of Constant Volume Tests.

Notes:

- *Residual material with respect to total charge material including 28.4-g cardboard tube used for charge fabrication.
- 1 psi = 6.9 kPa

Figure 1 shows an underwater shock pressure-time history comparison between a 260% HELP charge and a C4 charge. The C4 charge produces a high peak pressure and then begins a rapid exponential decay. At 2 ms the surface cut-off is observed illustrated by the drop in the pressure record to zero pressure. For the 260% HELP charge the peak pressure is lower and the pressure decay goes to a 1000 psi plateau between 0.5 and 2 ms before dropping to zero pressure. Also, only a slight drop in the pressure occurs at the arrival of the surface cut-off. These features match the original conceptualized HELP charge performance. However, the results shown in Figure 1 have not been able to be reproduced. Additional experiments that were performed with similar HELP charge mixtures did not show the extensive late time pressure plateau illustrated in Figure 1. This may be attributed to the charge fabrication technique. More underwater shock experiments are planned for FY99 along with Target E tilt rod mine vulnerability experiments to further assess the HELP charge performance.

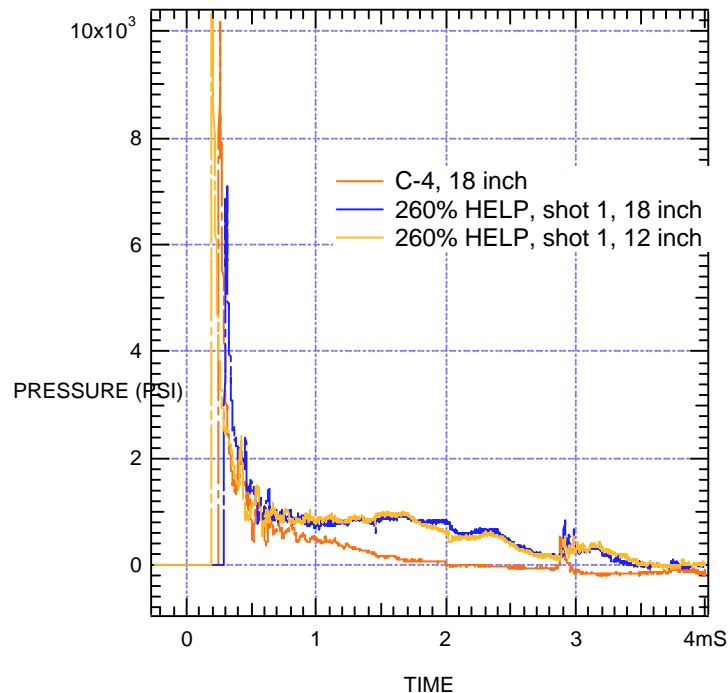


Figure 1. Shot 1 260% HELP and C-4 UNDEX Pressure Records.

IMPACT/APPLICATIONS

The calculations performed in FY98 illustrated that the HELP charge may produce up to a 35% increase in the lethal footprint for neutralization of Target E tilt rod SZ mines and SZ obstacles as compared to a M58 line charge. Experiments performed have shown some low pressure long duration characteristics that would support the computational results.

Other types of SZ mines and obstacles than the ones studied here may also be susceptible to HELP loads. For example, low pressure and long duration HELP loads may enhance the lethal footprint for neutralizing pressure plate mines by causing mine actuation in a manner as the mine was designed to operate. The increased bubble energy from a HELP source may enhance the damage to submarines due to the water jet phenomenology. Lastly, the HELP charge may produce larger plumes to provide enhanced protection of surface ships against low flying cruise missiles.

TRANSITIONS

Phase II of this effort is planned to be completed by May 14, 1999. If the remaining experiments indicate that the HELP charge produces a late time low pressure load which enhances the damage to Navy targets of interest, future work should address fabrication techniques, additional lethality investigations, and technology transfer from SRI to the Navy explosive development program.

RELATED PROJECTS

ONR sponsors improved energetic materials in 6.1, 6.2, and MANTECH programs. The proposed explosive is unique in that load duration is significantly longer than other explosives under development.