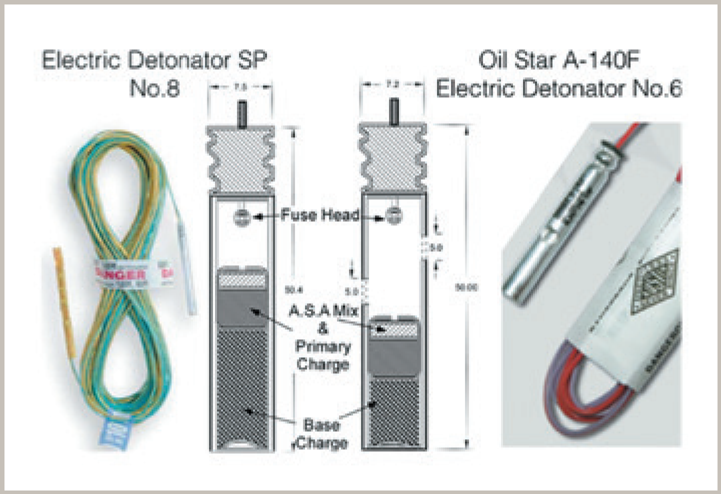
2016
CASE STUDY



Measuring Blast Wave Energy

The two standard detonators evaluated

Shadowgraph Optical Technique for Measuring the Blast Wave Energy Generated by a Standard Detonator

INTRODUCTION

This study overviews the detonation characteristics of standard electric detonators. Two detonators are characterized with this research. One is a fluid-desensitized oil and gas detonator, OilStar A-140F and the other is a standard mining and construction detonator, Electric Super™ SP. The measurement of the energy release from initiation systems is critical for the evaluation of their initiation ability of the firing sequence, as well as from the standardization point of view. Here, a new method is presented for experimentally measuring air shock properties and energy fluence from detonators with a single, small-scale experiment. High-speed imaging, in combination with the retro-reflective shadowgraph technique, effectively replaces older and imprecise manual measurement techniques, and produces data in general agreement with published data about detonation and air shock properties from high explosives. Indeed, this new characterization method should constitute a practical and simplified experimental tool for industry-use due to its relatively low cost, high data accuracy, and reduced data-analysis time.

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"Traditionally, detonator strength is characterized through indirect manual measurement techniques. These techniques require detonating an initiation system into a soft medium, or in some cases, next to a lead and/or metal witness plate, and then taking measurements in a time-consuming and imprecise process. The obvious replacement for these methods is high-speed imaging, which, in combination with the retro-reflective shadowgraph technique, constitutes as a practical and simplified experimental tool for industry-use due to its relatively low cost, high data accuracy, and reduced data-analysis time."

EXPERIMENTAL APPROACH

Shadowgraphy was invented as a visualization method in 1672, where the Sun was used to cast a shadow on a white surface. "Modern" shadowgraphy differs from this more rustic method in its use of specialized screens, light sources, and high-speed imaging systems. The direct shadowgraph technique is simple and robust, requiring only a light source, a high-speed imaging camera, and a screen on which to cast a shadow. In general, a light source is placed at an optimum distance from the screen and from refractive disturbances in the Schlieren object. A shadow is then projected at a certain height onto the screen. Retro-reflective shadowgraphy, specifically, requires the use of a retro-reflective screen and a rod mirror, which is aligned with the camera axis, illuminating the retro-reflective screen with a significant amount of light, and thus providing a high quality image. This technique is useful for the characterization of explosive energy, as it is able to measure blast wave parameters in the air.

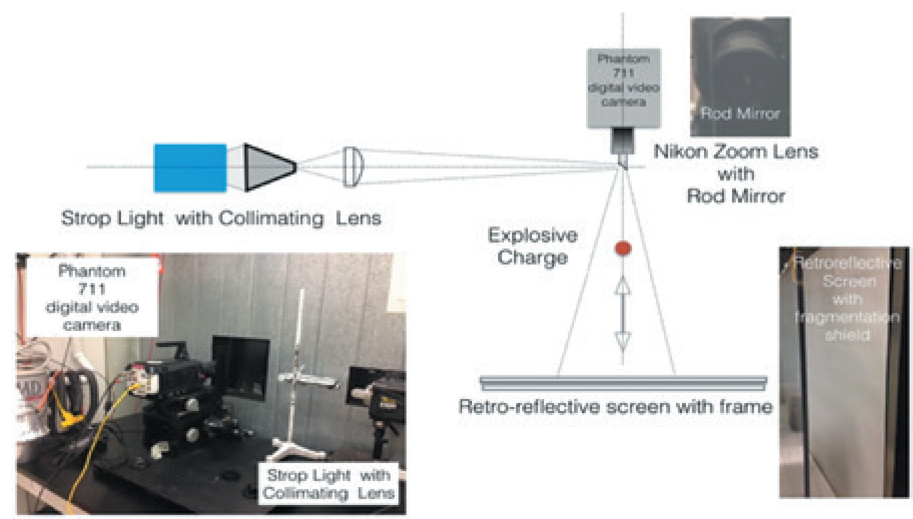

Figure 2: Retro-reflective shadowgraph experimental set-up (top view)

The experimental shadowgraph system shown in Figure 2, is elegant in its simplicity, robustness, and ease of use. The system is most appealing for small-scale blast chamber applications, as it consists only of a retro-reflective screen, a rod mirror, a high-speed imaging system, and a light source. The high-speed camera used is the Vision Research's Phantom v.711.

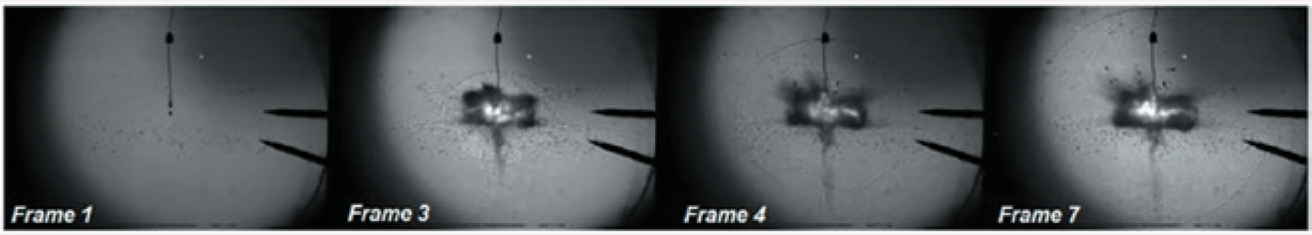

Figure 3: Frame sequence for electric detonator #6

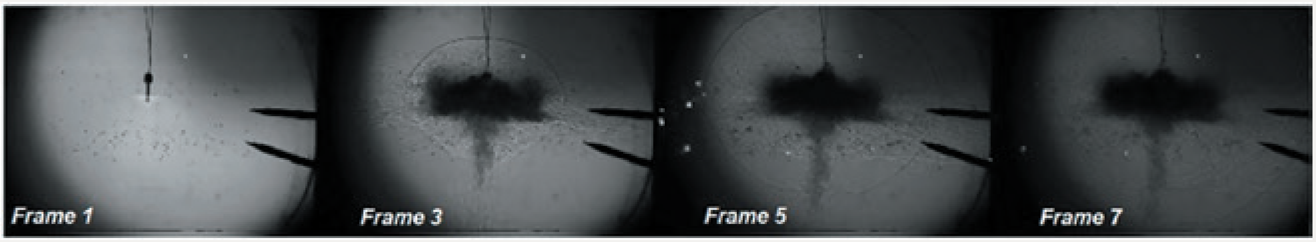

Figure 4: Frame sequence for electric detonator #8

Resolution of the image was set to 912 x 848 with a sample rate of 9,100 fps, and 0.294μs exposure. Some frame sequences for number 6 and number 8 detonators are presented above in Figures 3 and 4. As is shown, the initial blast wave presents a sharp elliptical shape due to charge geometry. As the shock expands, the spatial divergence and medium attenuation cause a gradual change in shape ending as a spherical shock wave (frame 7). Thirty number 6 electric detonators and fifty number 8 detonators were tested by the use of this method. This technical case study only reports the results obtained for one test per detonator as demonstration of the technique.

The ellipsoidal shock generated by the explosive charge produces higher shock velocity values in the transverse plane of the charge versus those recorded in the longitudinal axis. For this reason, the explosive energy delivered by the detonator will be different for each direction with respect its body. This difference will decrease as one move away from the center of the explosion as it will show in the following sections.

Additionally, the symmetry axis of a cylindrical detonator corresponds with its longitudinal axis and therefore seems reasonable to assume that the shock expansion in the normal plane of the camera view will be equal to the one recorded along the transverse direction. In order to accurately measure this third dimension, a second high speed camera would be required.

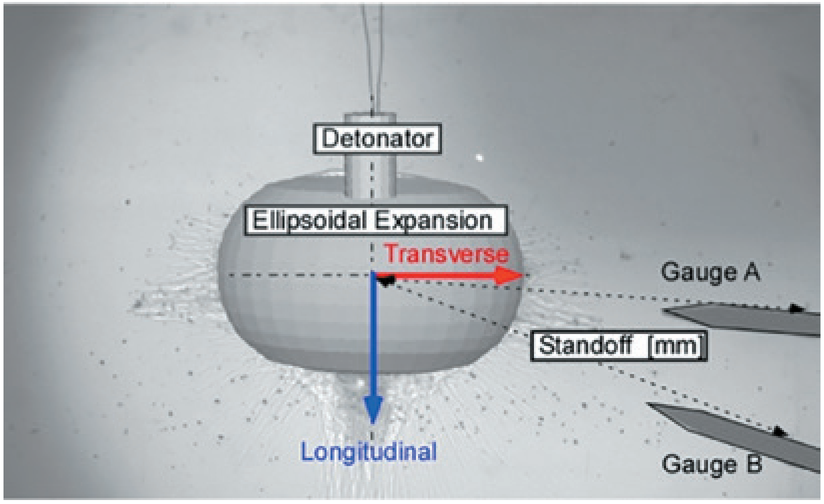

Figure 5: Approximated blast wave generated

CONCLUSION

High-speed imaging has proven to be a fast and accurate tool for characterizing the strength of detonators and blast waves in general. Vision Research's Phantom v.711 provided us with clear and precise images, from which we were able to measure the shock wave expansion rate from each initiation system, a and completely characterize the performance of the blast with a high level of accuracy. Because of their geometry, standard detonators show an initial ellipsoidal shock expansion that degenerates in a final spherical wave. This non-uniform shape of the shock derives in different blast overpressure values in the different directions. For this reason, transverse and longitudinal directions from the body detonator are studied along with an equivalent spherical blast for convenience purposes. Using the images captured, the shock Mach number versus distance was calculated, and a single yielding coefficient was obtained - this parameter is later related with the mass of casing surrounding the explosive charge. Finally, by considering the momentum absorbed by the detonator's shell, the total explosive energy contained within the detonator is calculated.

Phantom v.711

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