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ELECTROMAGNETIC DISTURBANCES ACCOMPANYING EXPLOSIONS

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An experimental investigation of electromagnetic disturbances produced by explosions is described. It is shown that the formation of the electromagnetic signal is governed mainly by the asymmetry of explosion-product scattering.

It has been shown experimentally [1-8] that the firing of explosives is usually accompanied by electromagnetic disturbances that can be registered by detectors placed at relatively large distances from the ground-zero point of the explosion. An investigation of the physical processes responsible for these disturbances may be of practical applied value but is also of independent scientific interest. However, no systematic study of this phenomenon has been published hitherto.

The present work discusses experimental results obtained in an investigation of explosion-induced electromagnetic disturbances. We studied the ways in which the electromagnetic signal was affected by different initiation methods, by the suspension height, mass, and shape of the explosive charge, and by external electric and magnetic fields. The generated electromagnetic signals were registered by means of vertical two-meter aperiodic-antenna rods, and were recorded with OK-17M, S1-20, and S1-29 oscillographs, which registered the following frequency ranges, respectively: 30 cps—10 Mc, 30 cps—20 Mc, and 30 cps—2 Mc.

The explosives were detonated in an open area, with the antennas located 5—30 m from the zero point. The charges were made of a 50/50 trinitrotoluol-hexogen alloy cast into spheres or cylinders weighing 1—5 kg. The oscillographic registers were triggered either by a signal from an ionization-type detector placed on an electrodetonator, or by a signal from a photocell. The influence of the method of initiation was investigated by using both an electric detonator and flame ignition.

Several characteristic properties were found in the electromagnetic signals accompanying explosions of spherical charges initiated by the electric detonator. Relatively brief irregular emissions, both positive and negative, of comparatively small amplitudes began at practically the very instant of initiation and terminated after tens of microseconds. These irregular spikes were replaced by a bell-shaped negative pulse of ~0.5-millisec duration having its maximum ~1 millisec after initiation. It was characteristic that the pulse shape and time interval t_m between initiation and the signal maximum were identical for spherical charges initiated at their centers and on their surfaces. No dependence was found on the height of suspension, direction of initiation, antenna distance, or even the strength or polarity of applied external electric and magnetic fields generated by special electrodes and coils. However, t_m revealed its quite definite dependence on the mass of the explosive charge:

$$t_m = KM^{1/3},$$

where t_m is time in milliseconds and M is the mass in kilograms of a cast TH-50/50 charge; our experiments yielded K = 0.7 ± 0.05. This dependence was determined through pulses from many charges having masses of 1, 3, or 5 kg. Good reproducibility of t_m was observed for each of these masses; the rms spread for each point was at most 2%.

Figure 1 is a typical oscillogram, registered at the explosion of a spherical 1-kg charge suspended at a height of 6 m. The antenna was located 20 m from the zero point of the explosion, which was initiated centrally by means of an electric detonator.

Flame ignition of spherical charges led to signals that differed markedly from those initiated by an electric detonator. Figure 2 shows oscillograms illustrating the first of these two cases. In the case of surface initiation the polarity of the signal depends on the direction of initiation. In the case of a spherically symmetrical explosion (central initiation) apparatus of identical sensitivity registers practically no signal.

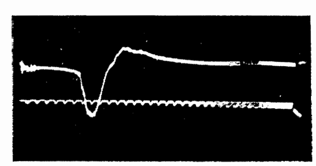

FIG. 1. Oscillogram of signals registered with a vertical antenna rod, at central electric-detonator initiation of a 1-kg spherical TH-50/50 charge suspended at 6 m. Zero-point-to-antenna distance 20 m; amplitude of initial part of signal ~ 5 V; duration Δt = 0.1 millisec.

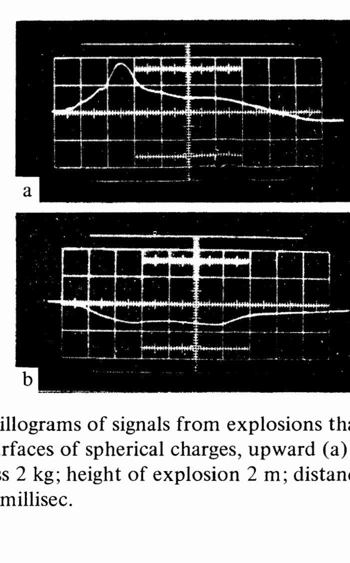

FIG. 2. Oscillograms of signals from explosions that were flame-initiated on the surfaces of spherical charges, upward (a) and downward (b). Charge mass 2 kg; height of explosion 2 m; distance to antenna 10 m; Δt = 1.0 millisec.

It should be noted that in the latter case any grounded conductor leading to the charge changes the picture; the signal then becomes identical with that for a spherical charge that is detonated electrically.

In the case of a cylindrical charge with a vertical axis of symmetry and flame-ignited at its lower end, the parameters of the electromagnetic pulse depend on the form of the cylinder. This dependence was shown with 1.3-kg charges having different height-to-diameter ratios H/d: 4.6, 2.0, 1.0, and 0.5. The explosions occurred 2 m above the earth's surface. Figures 3 and 4 are oscillograms showing that the signal amplitude depends on the distance from the antenna. The form $1/R^3$ of this dependence is characteristic of the near field in the case of a vertical dipole emitter.

When a cylinder having its axis placed in a horizontal position is exploded the signals reaching antennas placed on opposite sides of a plane perpendicular to the axis and passing through its center have opposite polarities. An antenna lying in the given plane receives practically no signals. When the direction of initiation is reversed the polarity of each signal is reversed.

Figure 5 shows oscillograms of signals registered by means of vertical antennas forming angles of 45° and 180° with the direction of initiation in the case of a cylindrical charge with a horizontal axis.

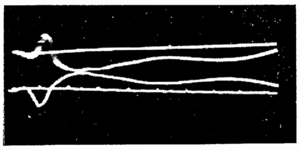

FIG. 5. Oscillograms of signals from a cylindrical charge with horizontal axis exploded by flame ignition at one end. Upper sweep-signal from antenna forming 180° with initiation direction (R = 10 m); lower sweep-antenna forming 45° angle (R = 8 m). Charge mass 1.3 kg; H/d = 4.6; height above surface of earth 3 m; Δt = 1.0 millisec.

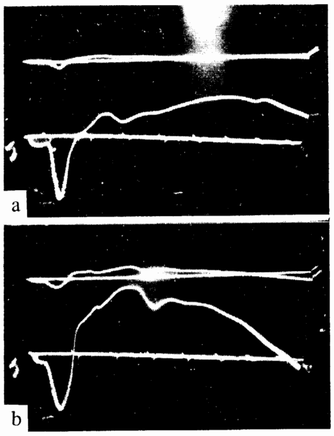

FIG. 3. Oscillograms of signals from cylindrical charges exploded by flame ignition at their lower end. The dimensional ratios of the charges were (a) H/d = 4.6 and (b) H/d = 2.0. Charge mass 1.3 kg; height above surface of earth 2 m; distance to antenna 12 m (upper sweep) and 8 m (lower sweep); Δt = 1.0 millisec.

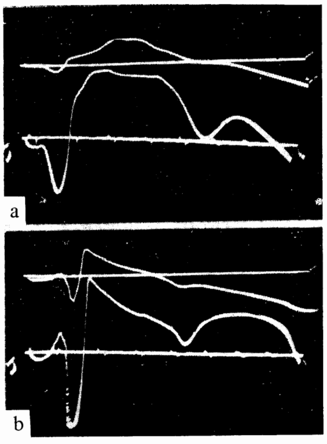

FIG. 4. Oscillograms of signals from cylindrical charges detonated by flame initiation at their lower end. The dimensional ratios of the charges were (a) H/d = 1.0 and (b) H/d = 0.5. Charge mass 1.3 kg, height above surface of earth 2 m, distance to antenna 12 m (upper sweep) and 8 m (lower sweep); Δt = 1.0 millisec.

In the case of flame ignition electric fields produced no detectable effect on the signals. Shielding of the electric field on the earth's surface and also the application of fields having different polarities and strengths up to 10^3 V/m in the explosion region failed to affect the signals. Magnetic fields of different polarities and strengths up to ~5 Oe also had no effect.

The foregoing experimental results indicate that the governing factor in the generation of electromagnetic disturbances is the asymmetry of the explosion. When an electric detonator is used this asymmetry appears to be determined by the current leads, which can introduce asymmetry into the distribution of electric charges. When an explosion is flame ignited the asymmetry depends on the geometry of the charge.

One can also assume, on the basis of the experimental results, that electromagnetic disturbances are generated by electric charges (or currents) that appear because the scattered explosion products are electrified. This hypothesis is supported by the appearance time of the signal, which begins some hundreds of microseconds after the detonation wave passes through the surface of the explosive charge. The facts that this signal-appearance time does not depend on the suspension height of the charge and that the strength and polarity of an external electric field do not affect the properties of the signal are inconsistent with Cook's hypothesis regarding the signal-generation mechanism.[5]

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92