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Fig. 1

Figure 1: Fig. 1

Abstract**Full Text****Physics****N. P. Novikov****On the Production of Strong Shock Waves under Laboratory Conditions***(Presented by Academician Ya. B. Zel'dovich, June 8, 1962)*

The most widespread methods for producing strong shock waves in glass tubes are based on the use of an impulse discharge in T-shaped and cone-shaped chambers (¹⁻⁶) or on the energy of an explosive charge (^{7,8}). In the present work, a method is proposed for producing strong shock waves in glass tubes under laboratory conditions by means of shaped-charge jets.

The detonation of shaped charges was carried out in a special explosion chamber (a metal tank about 1.5 m high), in which a rarefaction of 1 mm Hg was created. The charges did not exceed 120 g by weight and had a cylindrical shaped-charge cavity lined with iron. A glass shock tube of explosive action was attached to the lining; its schematic diagram is shown in Fig. 1. The shock tube consisted of a high-pressure chamber

Fig. 1. 1 –low-pressure chamber, 2 –branch tube for filling, 3 –high-pressure chamber, 4 –charge, 5 –lens, 6 –lining, 7 –transition nuts, 8 –diaphragm

(h.p.c.) about 300 mm long with an internal diameter of 36 mm, and a low-pressure chamber (l.p.c.) at least 500 mm long with an internal diameter of 30 mm; the l.p.c. and h.p.c. were separated by a diaphragm. The diaphragms in the shock tubes described were fastened as follows. The end of the l.p.c. tube was inserted into the h.p.c. tube; a diaphragm was glued to the ground end face of the l.p.c., and its edges were filled with sealing wax, while the h.p.c. tube was soldered to the l.p.c. tube. This fastening system was reliable and made it possible to create practically any pressures in the chambers. The diaphragms were made of aluminum 0.02 to 0.1 mm thick, designed so that they would withstand a pressure difference of not more than 200-400 mm. The h.p.c. and l.p.c. had branch tubes through which the chambers were filled with gas; the gas pressure (helium) in the l.p.c. did not exceed 400 mm, and the pressure of argon or air in the l.p.c. was not more than 100 mm.

The shock waves were recorded from their self-luminosity by an SFR instrument

Fig. 2

Figure 2: Fig. 2

(sweep and frame recording of the process). In this case it may be assumed that the propagation velocity of the luminosity coincides with the velocity of the shock wave, since, in the case of strong shock waves observed in our experiments, when they propagated in air or in argon with an admixture of 0.05% oxygen, the luminous front practically coincided with the shock-wave front⁽⁹⁾. Simultaneously with the sweep of the process, the spectral characteristic of the shock-wave luminosity was determined.

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Fig. 2. Framing rate $2.75 \cdot 10^6$ frames/sec. Argon pressure in the low-pressure chamber: **A** –30 mm Hg, **B** –100 mm Hg.

It may be assumed that the following physical processes will take place in the shock tube described. After detonation of the charge, a cumulative jet is formed (a stream of metal vapor with a density of 0.1–0.5 g/cm³), propagating at a velocity of 8–10 km/sec in the high-pressure chamber; like a piston, it compresses the gas in the high-pressure chamber; a shock wave is formed and approaches the diaphragm. After the shock wave interacts with the diaphragm, the pressure difference across the diaphragm rises sharply, the diaphragm ruptures, and a shock wave is formed in the low-pressure chamber (10–12); in the high-pressure chamber a reflected shock wave may also be formed. The proposed scheme is fairly simple; however, on its basis it is not possible to determine exactly the pressure difference at the moment of diaphragm rupture, since it is difficult to take into account the complex processes accompanying deformation and rupture of the diaphragm.

Table 1

Gas in the low- pressure cham- ber	θ , km/sec	M	P_1 , atm	P_2 , atm	ρ_2/ρ_1	T_2	α
Ar	10.7	32.8	0.0526	145.6	14.31	22000	0.55
Ar	9.2	28.2	0.0013	1.767	6.78	16000	0.84
Ar	8.2	25.2	0.118	133.07	12.27	18000	0.18
Ar	7.3	22.4	0.0013	1.067	9.327	12500	0.38
Ar	4.95	15.2	0.0131	4.806	6.83	10500	0.18
Ar	4.0	12.2	0.0013	0.282	6.70	7500	0.08
Air	9.0	26.3	0.0327	22.21	10.63	9900	0.493*
Air	6.8	19.8	0.131	50.07	9.15	8400	0.085*

* Concentration of free electrons.

From streak records of the process, the velocities of shock waves in the low-pressure chamber were measured, and then, knowing the initial pressure in the low-pressure chamber, all gas parameters in the shock wave were calculated. The calculation of the shock-wave parameters was carried out for argon by the method proposed in (13); here radiation in the shock wave was not taken into account, i.e., the parameter values were calculated for the region where cooling is not yet appreciably manifested. In the case of air, the gas parameters in the shock wave were found from tables (14, 15). The results of measurements of shock-wave velocities and calculations of the shock-wave parameters are given in Table 1, where θ is the shock-wave velocity; M is the velocity in Mach numbers; P_1 is the initial pressure in the low-pressure chamber, in atm; P_2 is the pressure behind the shock discontinuity; T_2 is the temperature behind the shock discontinuity; ρ_2/ρ_1 is the ratio of the densities before and behind the shock wave. From the results of the table it is seen that, with the aid of an explosive-action shock tube under laboratory conditions, it is possible to obtain powerful shock waves with velocities up to 10.7 km/sec (32.8 M) in argon at $P_1 = 40$ mm and up to 9.0 km/sec (26.3 M) in air at $P_1 = 25$ mm.

Analysis of the spectral characteristics of the radiation showed that, when the low-pressure chamber is filled with argon, lines of ionized argon are present in the spectrum, and when it is filled with air, lines of nitrogen and oxygen are present.

The results of high-speed framing are presented in Fig. 2 (see insert to p. 592). From the photographs it is seen that, during formation of the shock wave, the radiation begins not along the entire cross section of the tube but at some point, and only after 3–4 μ sec does the radiation cover the entire cross section, its front gradually becoming flat. Moreover, the higher the initial pressure in the low-pressure chamber, the faster the radiation front assumes a plane form (at a pressure of 2 mm the time for formation of a plane front is approximately 19 μ sec, while at 100 mm it is 10 μ sec). Hence it may be assumed that, after rupture of the diaphragm, the shock-wave front also does not assume a plane form immediately, but only after some time.

Thus, from the experiments described it follows that, under laboratory conditions, strong shock waves can be obtained in glass tubes by means of cumulative jets. The advantage of the method described is ...

are the reliability in operation of the shock tube and the absence of side effects that hinder the observation and analysis of the shock waves produced (for example, the strong electric and magnetic fields present in discharge tubes); a disadvantage is that, in the course of carrying out an experiment, the glass tube is destroyed and after each detonation a new one has to be made.

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