ABOUT THE CONTROL OF THE UNDERWATER AND ABOVEWATER NUCLEAR EXPLOSIONS BY HYDROACOUSTIC METHODS.

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ABSTRACT

The analysis of the experimental data available at the IDG which may be applicable to the problem of the detection and identification of nuclear explosions by modern hydroacoustic methods is represented. These data includes some results of observations of nuclear explosions at the Novaya Zemlya test site; results of measurements of HE with weights to 100 kg at a shallow reservoir; explosions of deep water bombs and mines; modeling of explosions of small charges of HE including underwater explosions in cavities filled by air.

On the basis of the analysis of the experimental data it was shown that methods of hydroacoustic control can be used for the detection and identification of nuclear explosions, which were conducted near bottom or the free surface of water, above water and at reservoir's coast including underground explosions. Application of high sensitive hydrophones established near the bottom of sea with low level of noise, existence of sound channels with small attenuation favor this inspection. From nuclear explosions conducted in confined reservoirs similar to the Bay of Chernaya, hydrophones can received signals in open sea from seismic waves before shock waves in water. These tests shows strong reducing effect of the bottom and free surface of the reservoir on the acoustic efficiency. Thus, it is necessary to conduct a special investigation for determining the advantages and disadvantages of the methods of hydroacoustic control respective to different methods. Special acoustic source function was developed which allows to determine parameters of acoustic signal at large distances before the acoustic wave comes into sound channel. Acoustic signals from various sources of natural and artificial origin: HE, impact of meteorites, earthquakes, tsunami and so on are used for identification of nuclear explosions.

List the key words: water, underwater, abovewater, explosion, HE, control, nuclear, hydroacoustic, method, shock wave, gaseous, bubble, bottom.

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In order to improve hydroacoustic methods of identification and control of underwater and abovewater nuclear explosions available experimental data on hydrodynamic processes in water induced by nuclear and chemical explosions in various conditions are considered. The data are important for construction of a general acoustic source function determining parameters of hydroacoustic waves at large distances from an explosion.

Approximately half of the explosion energy is transferred into shock wave from explosions in unconfined reservoir with the another half remaining in the gaseous bubble and radiated in the consequent oscillations. Energy remaining after dissipation of the shock wave in the near-field zone and energy of the gaseous bubble oscillations propagates at large distances as an hydroacoustic wave. The wave may propagate at large distances due to low attenuation in sound channels. Thus, hydroacoustic methods of control in a number of cases may be preferable. In the real conditions, the energy of acoustic waves in water is decreased by effect of the bottom and free surface of reservoir, that lead to decrease an efficiency of the control. That is why special comparative investigation for determining of advantages and lacks of methods of hydroacoustic control must be conducted. Special source function is helpful to be introduced. This function determines parameters of the acoustic wave coming into a sound channel or for different boundary conditions. In this paper we restricted to a number of experimental data, which showed the influence of real conditions of subwater explosions on its efficiency as a source of acoustic waves.

Specialists from the IDG RAS were taking part in the works of equipment design and measurements of mechanical, seismic and acoustic effects from all nuclear explosions. All the underwater nuclear explosions were conducted in shallow sea, when a large part of explosion energy is transferred into ground and air decreasing intensity of hydroacoustic disturbances. Motion of gaseous bubble was substantially changed as well as emitted into water energy was decreased due to venting of explosion products into the atmosphere. Hydroacoustic disturbances from above water explosions are produced by air shock wave and fall of a water column. The acoustic information on explosion source in known reservoir is obtained from analysis of amplitudes, duration and frequency content of measured signals generated by shock wave and following oscillations of a gaseous babble. The latter generates low frequency acoustic wave characterized by lower attenuation. So, further investigation of the parameters of shock waves and gaseous babbles is of great importance regarding with characteristics of reservoirs, propagation paths in ocean at different condition of explosions , as well as a possibility to conceal and identify the explosions from background noise from nature and technical explosion sources.

Several sets of sensors and recording equipment were designed as well as systems the distant control of the tests and equipment. They were used in natural and model tests with HE at different test sites and laboratory, as well as for investigations of propagation of hydroacoustic signals on large distances at explosions of deep water bombs and mines in sea since 1955.

From the nuclear explosions, the majority of the data for shock wave parameters were obtained by mechanical equipment, which was used in general.

A set of photographic cameras was used in order to record phenomena at the free surface in two perpendicular directions and from above from a plane. Surface waves were also measured by resistive gages with recording of signals onto recording strain gauge. Shock wave parameters in the atmosphere were recorded by a pressure recorder onto smoked paper.

The hydroacoustic signals from the deep water bombs were measured at large distances at ships, submarines and at the coast by different types of high sensitive hydrophones. In these experiments, industrial hydrophones with sensitivity of about 60 V/atm and frequency band above 5 Hz, hydrophones of ships with sensitivity of about 200-500 V/atm and frequency band above 5 Hz, and piezoelectric hydrophones with sensitivity of about 10 V/atm and frequency band above 4 Hz were used.

The investigations of hydroacoustic waves in wide range of distances from nuclear explosions were conducted for 3 underwater (21.9.55.-20 êò, 10.10.57.-small è 23.10.61 .small), 3 abovewater (13.9.61-small, 27.10.61-small, 22.8.62-small) and 1 coastal explosion on tower with height 15 m(7.9.57.-28 êò). Furthermore, an additional measurements were conducted for 3 underground explosions of large energy (27.10.66.-420 êò, 12.9.73.-2100-1600 êò, 29.8.74.-500-640 êò) at the coast of the strait of Matochkin Char.

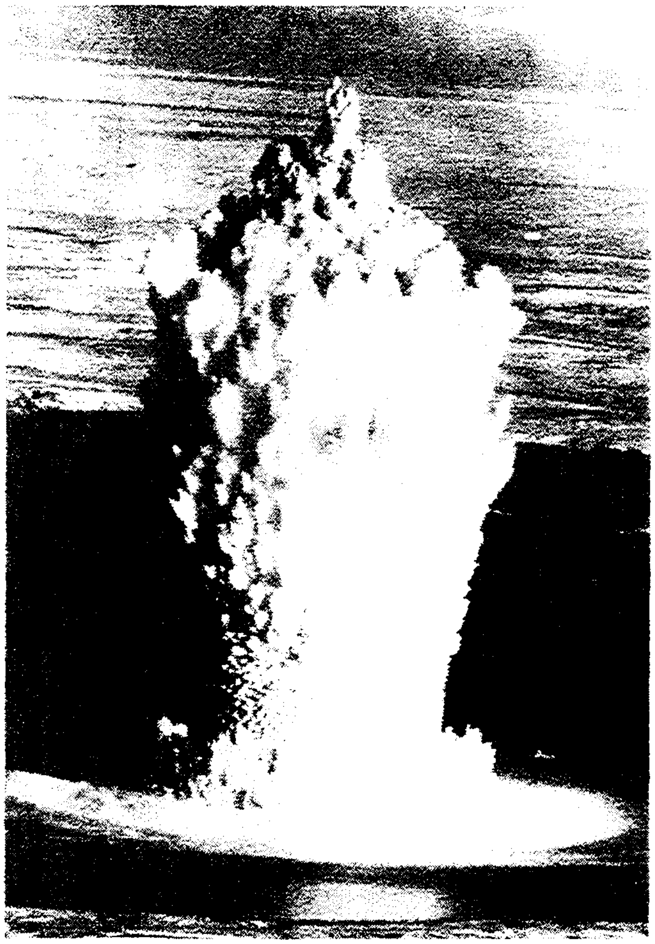

Fig. 1. A snapshot of the underwater nuclear explosion in 1957.

The nuclear device was placed at a depth of 20 to 25 m in the first test. All the underwater explosions were of approximately the same energy and were conducted at scaled depths $H^{*}=H/R_{0}$ = 2;5;2 respectively (Ro is the radius of equivalent TNT charge). A snapshot of the underwater nuclear explosion in 1957 is shown in fig. 1. The second explosion was fired at the bottom of the basin and the third at a depth of 20 m. The depth of the Bay of Chernaya beneath the point of the tests was of about 60 m. Therefore all the explosions were conducted in a shallow basin conditions. The closest analog of the explosions is the explosion "Baker". It was conducted by USA in July 1946 at the atoll of Bikini at a depth of 60 m. Another explosion, "Vigvam", with TNT equivalent of 30 kT was conducted at a depth of 610 m in a basin 1640 m deep within Pacific on 14.5.55.

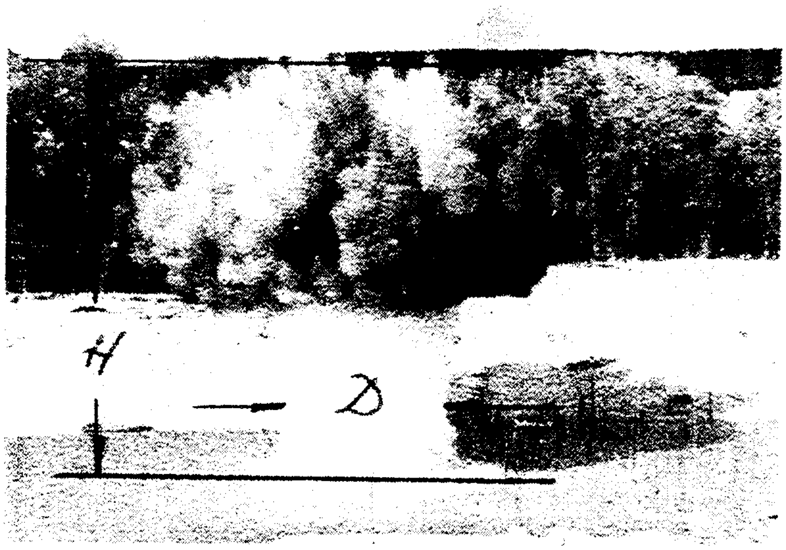

Fig. 2. A snapshot of an explosion of spherical charge of TNT with weight of 100 kg

Thus, the investigations showed that parameters of hydrodynamic process from explosions of close yields may change by an order of magnitude depending on conditions. HE explosions of different weight were conducted in shallow reservoirs with various types of bottom soils and depths in order to model nuclear explosion. This experiments based on the geometry and energy scaling law. Figure 2 displays a snapshot of an explosion of spherical charge of TNT with weight of 100 kg in the center of reservoir 3 m deep with sandy bottom. Figure 3 shows measured peak overpressure in shock wave against scaled distance from explosions in the centers of reservoirs of different depth. Overpressure and energy of hydroacoustic waves strongly decrease with decrease of the reservoir's depth because of increase of energy part transmitted into the air and ground. At the Black Sea, from explosion of 3000 kg in water with sound velocity gradients, shadow zones and peaks of acoustic signals induced by interference of sound waves in inhomogeneity liquid were observed.

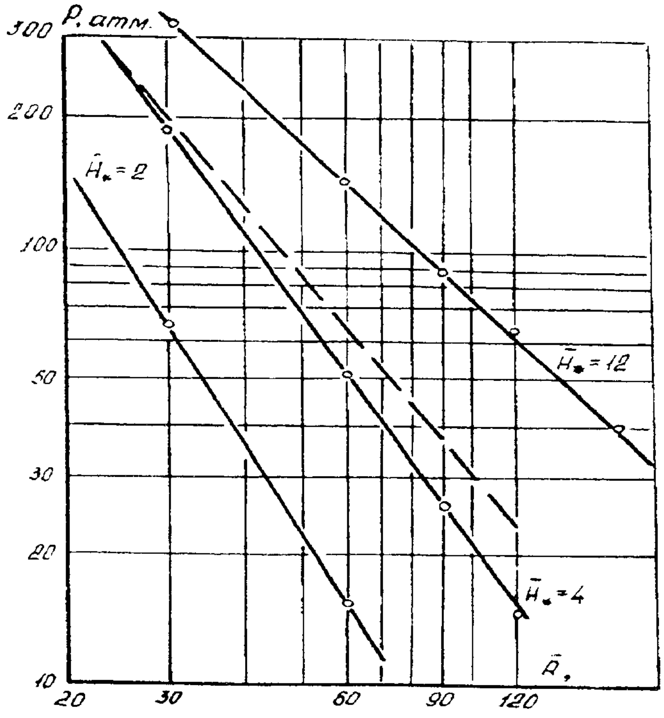

Fig. 3. Peak overpressure in atm in shock wave against scaled distance from explosions in the centers of reservoirs of different depth. $H_*=2R_0$, $4R_0$, $12R_0$. Dotted line is a nuclear explosion. R_0 is the radius of equivalent HE charge.

Propagation of hydroacoustic waves at large distances from explosions of deep water bombs was investigated in the Sea of Okhotsk by means of piezoelectric hydrophones in 1-1000 Hz

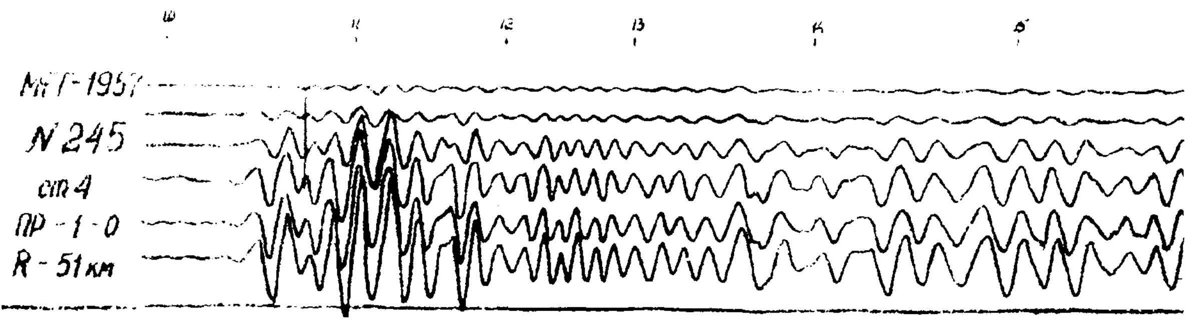

Fig. 4. Typical recordings of initial part of the signals from refracted in water seismic wave near bottom of sea area.

frequency range. The explosions at 10 to 300 m deep were recorded by submarine to a distance of 300 km and different depths.

Typical recordings of initial part of the signals from refracted in water seismic wave are shown in fig. 4. The ratio of signals from shock wave and following pulsation of the gas bubble against distance and depth was investigated from ships. This ratio decreases fast with increasing distance due to attenuation of high frequencies and the signals from the following pulsation become dominating. The waves reflected from the bottom and free surface as well as refracted waves arrive before the direct wave propagating in acoustic channel. The explosions can be detected at distances of several thousand kilometers. Capabilities of identification depend on conditions of the bursts. For example, acoustic signals from pulsation of bubble may not arise at near surface explosion.

Near bottom and near surface explosions, above water explosions, explosions with different volume concentration of energy, including explosions in air cavity for hiding and another questions of subwater acoustics were investigated in laboratory with small HE charges. Figure 5 shows that peak pressure, impulse and energy of shock wave appreciably decrease for an explosion in a cavity with increase of its

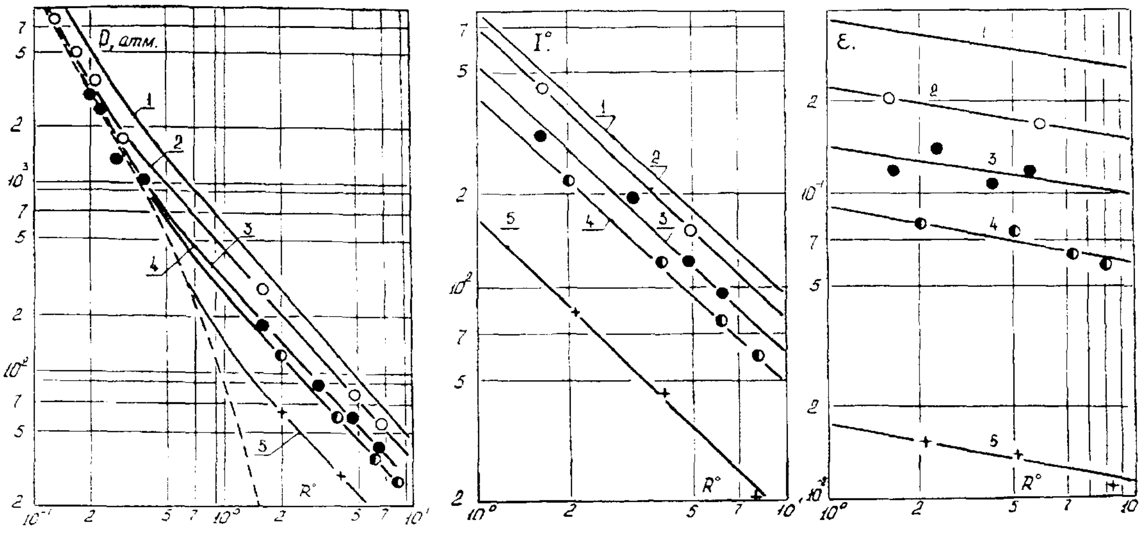

Fig. 5. Peak pressure P in atm, scaled impulse I_* in kg•s/m^2•kg$^{1/3}$ and ratio of energy of shock wave to explosive energy ε_* versus scaled radius R^0 in m/kg$^{1/3}$ for subwater explosion in air cavity. 1,2,3,4,5 are R_1/R_0=1, 2.64, 3.92, 5.0, 11.9 respectively. R_1 is the radius of cavity.

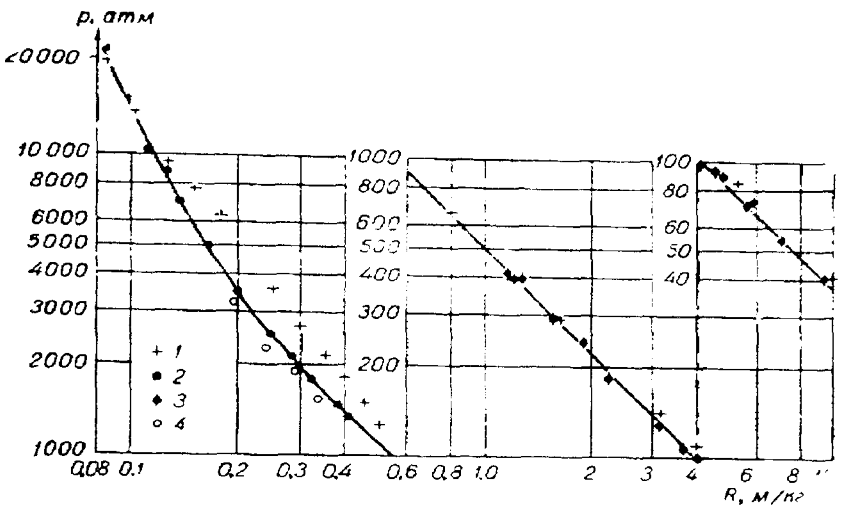

Fig. 6. Peak overpressure in atm in shock wave versus scaled distances in m/kg$^{1\ 3}$ for explosion of PETN with density of 0.4 g/cm^3.

radius. Accordingly, the energy of hydroacoustic disturbances generated by the shock wave have to decrease at large distances. A problem of similarity of shock waves is considered. It was shown, that shock wave parameters depend on energy concentration, E/V, in the source of an explosion. At increasing the ratio of E/V, the energy propagating at large distances is increased due to increase of a part of initial energy transferred into water by the explosion. This energy reaches maximum value at E/V corresponding to TNT explosion and decreases beyond by two times for nuclear explosion because of energy dissipation in the nearest zone [2-5].

There was an attempt to construct a source function for explosion in unconfined liquid space which determines energy of acoustic disturbances at large distances. In order to construct this function, measured time history of explosion product's radius for PETN with density of 0.4 g/cm^3 was fixed and then wave field in water was calculated numerically. The comparison of predicted and measured data of peak pressure against distance is shown in fig. 6. It can be seen that intensity of hydroacoustic signal at large distances may be determined from the available results of measurements in the nearest zone by such a procedure. Apparently, this method may be used for explosion in shallow reservoir and above water explosion.

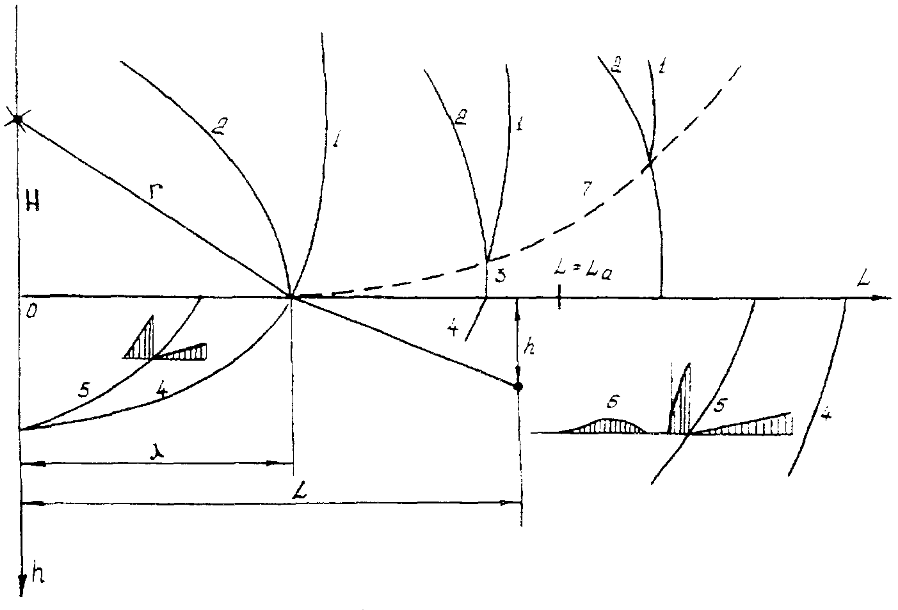

Fig. 7. Wave pattern for above water explosions. 1,2,3 -Direct, reflected and Mach waves in air. 4,5,6-refracted, epicenter and pressured waves in water.

In the model experiments with above water explosions, the complicated wave pattern (see fig. 7.) was recorded. The pattern consists from refracted air wave, epicenter wave, which is generated by a shock of explosive products, and pressured wave, associated with delaying propagation of air wave.

Typical details of the flow and its parameters in the nearest zone are shown in fig. 8 for TNT explosion of 1 KT at the air-water boundary, which was determined for three times by means of model investigations with shock wave velocity in water less, then in air. Pressure in atmospheres (bars) and distances in meters were pointed along vertical and horizontal axis respectively. The results of measurements of shock wave parameters in water at large distances from an explosion of TNT spherical charge of 100 kg in 3 m reservoir at surface are shown in fig. 9. In this case, shock wave velocity in water is larger than in air. Recalculation of this data considering scaling to TNT charge of 1 KT gives following peak values of parameters (in reservoir with a depth of 12 charge's radius): at $R_*=60$ or $R=318$ m - pressure $P_m=72$ atm, duration $\tau_m=3.45$ ms, specific pulse $I_m=1400$ kgs/m^2 and at $R_*=120$ or $R=636$ m - $P_m=27$ atm, $\tau_m=2.6$ ms, $I_m=320$ kgs/m^2.

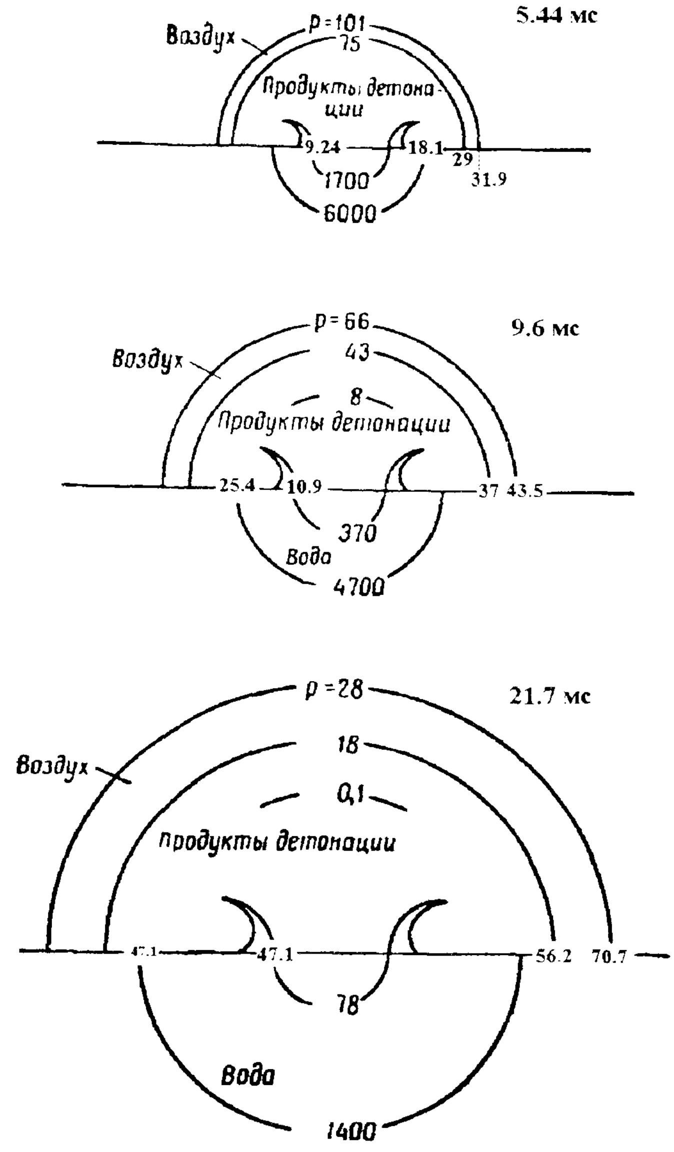

Fig. 8. Typical details of the flow for TNT explosion of 1 KT.

In accordance with the model investigations, the maximum radius of gas bubble is of 157 m and the period of the first pulsation is of 24 s for TNT explosion of 1 KT in unconfined liquid space with ambient pressure of 1 atm. Vertical radius of 170 m and period of 190 s will be for explosion at the free surface. The period increase is due to venting of gaseous products into atmosphere. During this process, pressure in the bubble does not decrease below atmospheric, back motion and subsequent oscillations of the bubble are absent. This may hamper identification of hydroacoustic signals from explosion at large distances.

Modeling of meteorite impacts at the water surface was conducted by means of a shock of high speed plasma jet. The results of measurements of shock wave and bubble were compared with the data from subwater and surface explosion with the aim of determining of TNT equivalent of the impacts

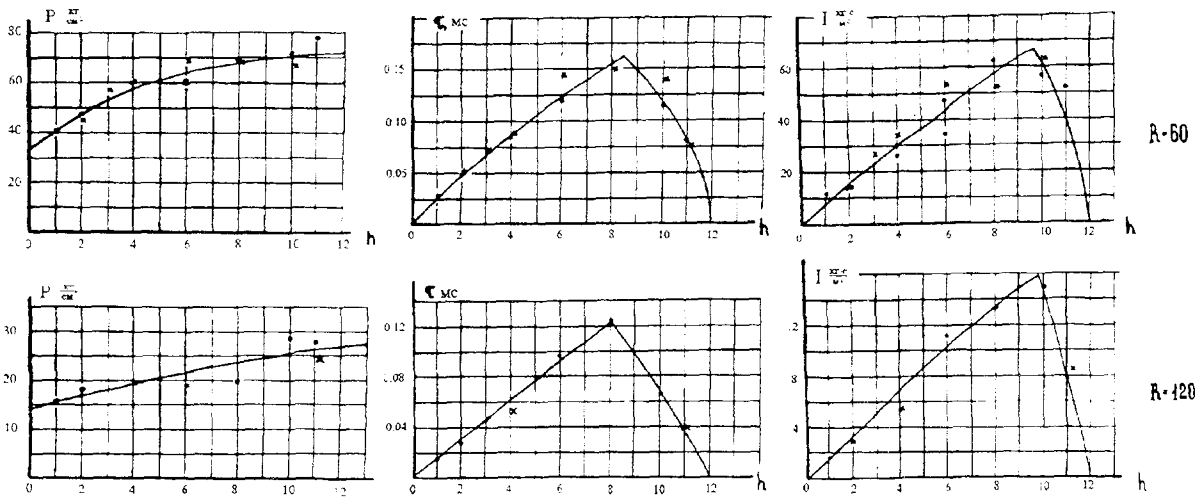

Fig. 9. Peak overpressure in atm, duration in ms and specific impulse in kgs/m^2 of shock wave in water for an explosion of TNT spherical charge of 100 kg. R_*, h - distances and depth of probe in radius of charge R_0 = 0.246 m.

[6]. This investigation may be used for determination of source function and identification of different explosive events.

The investigations and analysis of the experimental data showed that hydroacoustic method of control may be used for detection and identification of nuclear explosions, conducted at different conditions, including near bottom and free surface, near water surface, coasts of opened reservoirs (including underground explosions). Usage of hydrophones based on high sensitivity piezoelectric ceramics with reliable contact to water and relatively low noise level near the sea bottom, existence of sound channels in the majority sea areas characterized by propagation of sound to thousands kilometers with low attenuation favors detection. Hydroacoustic equipment allows to measure waves of seismic origin, traveled in ground, which are recorded before shock wave in water if an explosion was conducted in a confined reservoir like the Bay of Chernaya. It is necessary to use hydroacoustic signals from another natural and artificial sources, such as earthquakes, tsunami, HE and so on for identification of nuclear bursts. It is also necessary to elaborate their source functions which will determine acoustic wave parameters at entrance to waveguide.

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