COLLAPSE OF MICROOBJECTS INITIATED BY A LASER PULSE IN WATER AT REDUCED PRESSURE

P. I. Golubnichii, P. I. Dyadyushkin,
G. S. Kalyuzhnyi, and V. G. Kudlenko

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Plasma phenomena have been discovered fairly recently which accompany the collapse of nonuniformities initiated by laser breakdown in different liquids. We are referring to the occurrence of short ($t < 10^{-7}$ sec) light pulses and accompanying shock-acoustic pulses formed several tens of microseconds after the initiation of the nonuniformity [1, 2]. This time interval which separates the instant of initiation and the instant of collapse of the microobject is the period of pulsation of the cavern which occurs at the point of laser breakdown.

In order to study the mechanism of the physical processes accompanying collapse, it is of interest to investigate the dependence of the main parameters characterizing this phenomenon on the thermodynamic conditions.

In this paper we examine experimentally the change in the pulsation period T of the cavern and the amplitudes of the shock-acoustic pulses A occurring during collapse due to a reduction in the static pressure down to 0.1 atm.

A block diagram of the apparatus employed is shown in Fig. 1. A pulse from an OKG-11 laser with an energy of 10^{-2} J and duration 10 nsec was focused by a lens of focal length 4 cm (2) onto a chamber filled with water 3. The pressure in the chamber, monitored by means of a manometer 4, could be reduced by means of a fore-vacuum pump 5. The acoustic pulse occurring when the vapor-gas nonuniformity collapses was recorded with a hydrophone 6, made of TsTS19 piezoelectric ceramic. The resolution time of the hydrophone was 0.5 μsec. The signals received by the hydrophone were applied to an S8-2 recording oscilloscope 7. The period of the pulsations was determined from the distance between pulses on the oscilloscope sweep corresponding to breakdown of the liquid and collapse of the nonuniformity. The laser pulse energy was periodically monitored with an IKT-1M solid-state calorimeter 8 and a mirror 9.

The dependence of the pulsation period of the cavity T on the static pressure p is shown in Fig. 2. Each point was obtained by processing 100 oscillograms. The curve corresponds to a relationship of the form $T \sim p^{-0.86}$. The exponent was obtained as the slope of the line obtained by the method of least squares drawn through the experimental points in log p, log T coordinates. An estimate of this slope gave a value of tan ± = −0.86   0.1.

The theoretical relation for the pulsation period of the cavity as a function of its energy and the static pressure is given by the equation [3]

$$T = 1.14\rho^{1/2}E^{1/3}/p^{5/6},$$

where ρ is the density of the liquid, E is the energy of the cavity, and p is the hydrostatic pressure. This disagreement between the experimental and theoretical values of the exponent for p may be due to slight deviations of the shape of the actual bubbles from spherical. We can also conclude that the energy of the cavity does not change when the static pressure changes from 1 atm to 0.1 atm. Since

$$E = (4/3)\pi R^3 p,$$

where R is the maximum radius of the nonuniformity, we have $R \sim 1/p$.

Figure 3 shows the amplitude of the acoustic pulse A as a function of the pulsation period of the cavity for different values of the static pressure. It is seen that for constant p the dependence of A on T is approximately linear. This is also confirmed by results of investigations on the collapse of nonuniformities initiated by a spark or by exploding wires [4].

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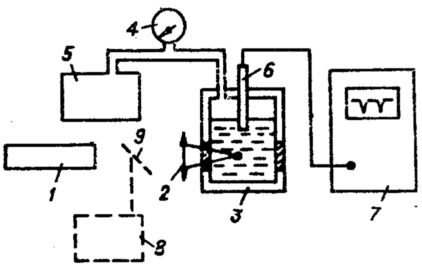

Fig. 1

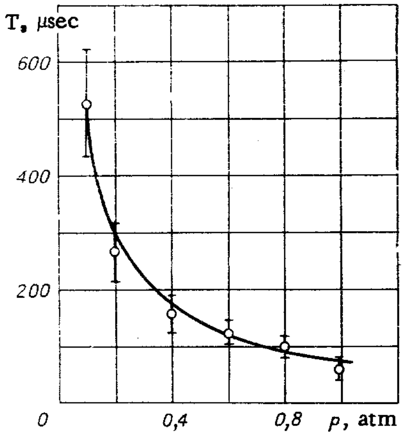

Fig. 2

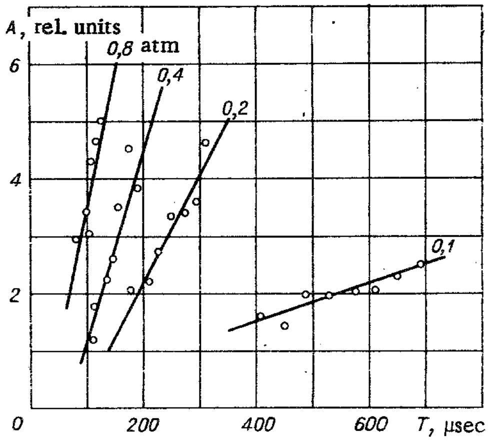

Fig. 3

The pressure in the shock wave formed when the bubble collapses can be estimated from the equation [3, 5]

$$A = \rho r^3/\tau^2 l,$$

where r is the radius of the cavity reached at the end of the energy dissipation, at the instant of time τ, and l is the distance between the bubble and the acoustic receiver. According to [5], $r^5 \sim {}^2E$. Since $R \sim Tp^{1/2}$ [3], we have $A \sim (R/r)^2 p^{3/2} T$.

Since it follows from the experimental data that A depends linearly on T, we can assume that R/r = const for fixed p.

The slopes of the lines in Fig. 3 at reduced pressures down to 0.2 atm decrease somewhat less than would follow from the relationship $A \sim p^{3/2}T$. This can be explained if we assume that the value of the ratio R/r depends on the value of the static pressure and that the ratio R/r increases as the pressure is reduced.

At reduced pressures from 0.2 to 0.1 atm the slopes of the lines decrease much more than would follow from the relationship $A \sim p^{3/2}T$. It is probable that in this pressure range the nonsymmetrical nature of the collapsing bubbles plays a more important role, leading to a reduction in the amplitudes of the shock-acoustic pulses. It should be noted that the lack of symmetry of the bubbles increases as the pressure is reduced, since bubbles of larger radius are less stable.

The average amplitude of the acoustic pulses at reduced pressures from 1 atm to 0.1 atm atm decreases by 40%.

In conclusion, we draw attention to the possibility of using the results obtained, and, in particular, of the artificial "extension" of the lifetime of initiated nonuniformities, in the practical realization of the method of detecting nuclear particles with large specific energy dissipation described in [6]. The increase in the maximum dimensions of the nonuniformities (i.e., the additional possibility of visualizing them) at reduced static pressures is also of interest.

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SURFACE EFFECTS FROM AN UNDERWATER EXPLOSION (REVIEW)

V. K. Kedrinskii

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INTRODUCTION

The surface effects accompanying an underwater explosion represent an integral combination of many interconnected phenomena. Among these we include the special characteristics of the wave field structure, which is determined by the existence of regions of regular and irregular shock-wave reflection from the free surface with sharply differing structure and parameters, the development of cavitation and the formation of a cupola, vertical and radially directed eruptions, which can originate almost simultaneously or alternately, and surface waves. The significant change of shape of the cavity with the detonation products pulsating in the vicinity of the free surface exerts an effect on the nature of the development of the surface eruptions and on the secondary pressure field in the liquid.

As an independent trend in the field of explosion hydrodynamics, investigations of the surface effects from underwater explosions already have a 60-year history. Two of the most fruitful stages of their development may be mentioned: foreign investigations of the 1940's [1, 2] and Soviet investigations in the 1950-1960's [3-10]. One of the first papers in this field is the report of Hillar (1919), mentioned in [2] and devoted to the investigation of the mechanics and parameters of cupolar formation at the surface of a liquid. In this paper an analogy is drawn between the mechanics of cupola formation and the Hopkinson effect (1914), and the suggestion is made that the initial velocity of its ascent for relatively weak shock waves should be characterized by twice the post-shock particle velocity. It is well known that this hypothesis was largely verified by numerous later experiments. Anomalies have been recorded only for the case of the explosion of large-scale charges [1] and have not been explained up to the present.

In [1], the results of investigations of mainly large-scale explosions of charges with weights up to 450 kg were generalized and the relationship between the dynamics of the explosion cavity with the formation of plumes and the characteristics of the parameters of the secondary pulsations was established. The surface effects from underwater nuclear explosions are discussed in [11]. Reference [2], which was issued almost simultaneously with [1], should be specially mentioned, since it is the first and (up to recent times) only attempts to give an analysis of the mechanics and structure of the throwouts at the free surface. This paper is not widely enough known among the circle of specialists in the field.

The first results of a theoretical analysis of the nonlinear interaction of shock waves with the stress relief waves from the free surface were published in [3], which investigated the structure and parameters of shock waves and determined the boundary of the region of irregular reflection. In [4] this problem was studied experimentally, in [5] the solution of the two-dimensional problem concerning the reflection of a spherical shock wave from a free surface was obtained, and in [6] a number of approximate analytical relations, connected with estimates of the parameters of the wave field, were given.

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