To determine the absolute coefficients of recording of x-ray and gamma quanta by such a converter we calibrated the converter on standard gamma sources. The results of the calibration using the standard procedure are given in Table 1, where column 4 shows the coefficients of recording with direct irradiation of the surface of the MCP with x rays (normal incidence), while column 5 shows the recording coefficients for recording of x-ray quanta by the system Fig. 2a. The much higher recording coefficients can be explained by the much higher quantum yield of PbO than of Si_2O_3(Pb) and the well-known fact that the quantum yield is higher for glancing incidence.

The experiments performed and the analysis of the possibilities for expanding the dynamic range for recording images show that it is possible to develop a compact image amplifier with high spatial and temporal resolution; such an image amplifier is being used in the development of an Auger spectrometer and multichannel analyzer of flows of atoms [6].

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LIMITATION OF CUMULATIVE PROCESSES IN THE COLLAPSE OF A BUBBLE IN A LIQUID

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The converging motion of an incompressible liquid is known to result in a local buildup of kinetic energy of the liquid. In such cumulative processes, at least theoretically [1], it is possible for energy to become concentrated in an infinitesimal volume and for infinitely large pressures and temperatures to develop. Obviously, such a cumulative process is always limited in practice by the nonideal nature of the liquid itself; viscosity, thermal conductivity, and compressibility must be taken into account [2, 3]. These effects do not alter the general behavior of the converging flow and play a major role in estimating the physically attainable limiting parameters of the cumulative process. A dimensional analysis shows [4] that such an important cumulative problem as the Rayleigh problem [5] admits the formulation of a cumulative-bounded solution if allowance is made for the thermodynamic properties of the residual gas in the bubble interior. The dynamic flow pattern in this case has been studied in detail in a number of papers [6, 7]. In the present study we discuss the analysis of flow stability in connection with the collapse of a gas bubble in a liquid.

It is usually attempted in the investigation of the motion of an energy-accumulating liquid to obtain a reliable picture of the pressure field inside the liquid [7]. For an in-

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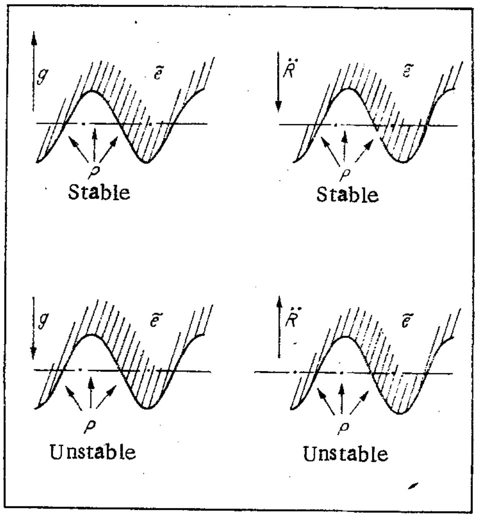

Fig. 1

compressible liquid, however, the internal energy is not related to the pressure [8] and so it is important to consider the characteristics of the conversion of bubble potential energy into kinetic energy of the liquid during collapse. We write the expression for the collapse rate

$$(\dot{R})^2 = \frac{2}{3}\frac{p_0}{\tilde{\rho}}\left[\left(\alpha + \frac{1}{\gamma-1}\right)\left(\frac{R_0}{R}\right)^3 - \left(\alpha + \frac{1}{\gamma-1}\left(\frac{R_0}{R}\right)^{3\gamma}\right],$$

where $\tilde{\rho}$ is the density of the liquid, $\alpha = \tilde{p}/p_0$ is the ratio of the pressure in the liquid far from the cavity boundary to the initial pressure of the gas in the cavity interior, γ is the adiabatic exponent of the gas, and R_0 and R are the initial and instantaneous radius of the cavity, respectively. It is evident that the rate is a maximum when

$$\frac{R_0}{R} = \left[\frac{\gamma-1}{\gamma}\left(\alpha + \frac{1}{\gamma-1}\right)\right]^{\frac{1}{3(\gamma-1)}}.$$

Since $\ddot{R} = \frac{1}{2}\frac{d}{dR}(\dot{R})^2$, the acceleration of the cavity boundary is zero at the point of maximum collapse rate. At the start of the collapse process $\ddot{R} = \frac{p_0}{\tilde{\rho}R_0}(1-\alpha)$ or $\ddot{R} \simeq -\frac{\tilde{p}}{\tilde{\rho}R_0}$ for $\alpha \gg 1$.

We also calculate the variation of the kinetic energy of the liquid during the motion:

$$\Delta E_{\text{K}} = 4\pi\int_R^\infty \tilde{\rho}\frac{v^2}{2}r^2dr$$

(v is the velocity of a liquid particle with the coordinate r). The integration must be extended to ∞ in correspondence with the initial conditions of the problem [5]. Consequently,

$$\Delta E_{\text{K}} = \frac{4}{3}\pi\tilde{p}[R_0^3 - R^3] + \frac{4}{3}\pi p_0 R_0^3\frac{1}{\gamma-1}\left[1 - \left(\frac{R_0}{R}\right)^{3(\gamma-1)}\right].$$

The first term of this expression corresponds to the variation of the potential energy of formation of a spherical cavity in a given pressure field, and the second term is simply the increment of the internal energy of the residual gas in the adiabatic approximation [1], i.e., $\Delta E_{\Pi} = \Delta E_K + \Delta E_{in}$.

The liquid is accelerated throughout the entire process of collapse of the cavity. However, the accelerated motion of an incompressible liquid can be unstable. This refers specifically to Rayleigh–Taylor instability, which occurs, e.g., in the motion of an incompressible liquid in a gravity field [9]. We use the latter model, replacing the force of gravity by an inertial force directed oppositely to the acceleration of the liquid. At the start of the collapse process, the acceleration is directed toward the center of the bubble. In this case, according to the theory, disturbances develop and grow at the rate $\omega^2 \sim |\ddot{R}|k$, where k is the wave vector and ω is the angular frequency of the disturbance. If the motion took place in a gravity field, the surface of the liquid would vary according to the law $\tilde{y} = y_0 \operatorname{ch} \omega t \cdot \cos kx$. Here ω is given by the expression $\omega^2 \cong \pm gk$, where the plus sign corresponds to the case where the liquid is subjected to pressure acting against gravity and instability sets in, and the minus sign corresponds to the opposite, stable situation. As mentioned, we now replace the force of gravity by an inertial force with allowance for the sign of the acceleration. It then turns out that the motion is stable up to the maximum velocity and is unstable after the maximum velocity. Figure 1 illustrates these considerations. Thus, Rayleigh–Taylor instability sets in during the collapse of a spherical gas-filled bubble.

It has been shown above that the real collapse of a bubble in a liquid seldom results in any appreciable accumulation of energy, because Rayleigh–Taylor instability sets in during the final stage of collapse. The cumulative process in the given situation is based on the conversion of the potential energy of bubble formation into kinetic energy of the converging flow. On the other hand, the variation of the bubble size during collapse causes the thermal energy of the gas in the bubble interior to increase and causes the probability of further acceleration of the liquid to decrease. In other words, both the kinetic energy of the liquid and the thermal energy of the gas have the same source: the potential energy of formation of the bubble. The process of conversion of this energy in cumulative problems is irreversible, and so the cumulative process must cease once the total current store of potential energy has been exhausted. The subsequent motion of the liquid is unstable. It can therefore be postulated that the physical causes of the Rayleigh–Taylor instability in the given situation are the special attributes of the evolution of the energy balance of the total system comprising the liquid and the residual gas inside the bubble.

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