5. F. M. Babenko, L. V. Borshch, N. M. Levchenko, et al., Experimental Investigation of the Temperature Distribution in Rotating Helium-Filled Cavities [in Russian], Preprint No. 36, Low-Temperature Physicotech. Inst., Ukr. Acad. Sci. Kharkov (1984).
6. Yu. A. Kirichenko, N. M. Levchenko, K. V. Rusanov, et al., Heat Transfer Processes in Liquefied and Solidified Gases [in Russian], Kiev (1980), pp. 44-51.
7. Yu. A. Kirichenko, S. M. Kozlov, and N. M. Levchenko, Izv. Akad. Nauk SSSR, Énerg. Transport, No. 5, 128-134 (1982).
8. Yu. M. Pavlov, S. A. Potekhin, and A. V. Paramonov, Tr. Mosk. Énerg. Inst., No. 427, 10-15 (1979).
9. I. A. Glebov, I. P. Vishnev, V. G. Pron'ko, et al., Izv. Akad. Nauk SSSR, Énerg. Transport, No. 4, 3-9 (1980).
10. S. A. Potekhin, "Investigation of heat transfer and crises during helium boiling," Abstract of Candidate's Dissertation, Moscow (1981).
11. Yu. A. Kirichenko, S. M. Kozlov, K. V. Rusanov, et al., Processes of Heat and Mass Transfer in Cryogenic Systems [in Russian], Kiev (1981), pp. 34-46.
12. Yu. A. Kirichenko and S. M. Kozlov, Model of Heat Transfer for Nucleate Boiling in a Centrifugal Force Field [in Russian], Preprint No. 24, Low-Temperature Physicotech. Inst. Ukraine Acad. Sci., Kharkov (1982).
13. R. Bellman and R. H. Pennington, Q. Appl. Math., 12, 151-157 (1954).
14. Yu. A. Kirichenko, K. V. Rusanov, and E. G. Tyurina, Film Boiling of Helium [in Russian], Preprint No. 8, Low-Temperature Physicotech. Inst., Ukr. Acad. Sci., Kharkov (1982).
15. N. M. Levchenko, E. P. Levchenko, and E. A. Golovleva, Teploénergetika, No. 4, 42-45 (1986).

ATTENUATION OF THERMAL PHONON GENERATION BY A METALLIC FILM UNDER ITS PRELIMINARY PULSE HEATING

V. N. Lisin, B. M. Khabibullin,
E. P. Khaimovich, and A. M. Shegeda

UDC 536.423.1:536.483

It is detected experimentally that during heating of a metallic film by two short current pulses that cause helium boiling, restoration of the contact between the film and the helium occurs much more rapidly than during heating by one pulse.

As the amplitude and shape of thermal pulses passing through specimens change, information can be obtained not only about the characteristics of a given crystal but also about the conditions for phonon passage through the heater-liquid helium boundary. Thus, the magnification of thermal phonon radiation in thin metallic film specimens was detected in [1] if a powerful current pulse were first delivered to it. Under the effect of this pulse the liquid helium at the film surface was transformed into vapor. The drift of the phonons generated in the film by the test current pulse was negligibly small in the gaseous helium. Consequently, those phonons which departed earlier into the liquid helium from the heater are radiated into the specimen, which results in magnification of the radiation. Here that current pulse which in itself does not cause boiling of the helium is called the test pulse.

The case when preliminary heating is realized by two pulses is examined in this paper. It was show in [1] that a finite time t_{12} after the first powerful pulse Q_1 only part of the heater is in contact with the liquid helium, the rest is covered by vapor. It is expected that if a sufficiently powerful second current pulse Q_2 is passed at this time through the film, then the liquid helium at the heater surface should evaporate. Consequently, if a test current pulse Q_3 were to be fed to the film after Q_2, then the phonon radiation generated by the pulse Q_3 in the specimen should be greater than in the case when $Q_2 = 0$. However, it was detected experimentally that radiation of the test pulse rapidly drops in magnitude and is compared with radiation without preliminary heating after several microseconds ($Q_1 = Q_2 = 0$). This

Physicotechnical Institute, Kazan Branch, Academy of Sciences of the USSR, Kazan. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 54, No. 3, pp. 374-382, March, 1988. Original article submitted November 25, 1986.

 0022-0841/88/5403-0246$12.50

means that after delivery of two powerful current pulses to the heater, the heater area covered by the vapor diminishes despite expectations, more rapidly than in the case considered in [1].

METHODOLOGY OF THE EXPERIMENT AND EXPERIMENTAL RESULTS

The experiment was the following. A copper heater of $S = 0.387 \cdot 10^{-6}$ m² area and thickness $d = 0.06$ μm with a resistance $R = 50\ \Omega$ at helium temperatures was sprayed in a vacuum on one of the $Al_2O_3:Cr^{3+}$ specimen endfaces of diameter 11.5 mm and 14 mm length. A superconducting indium bolometer was sprayed on the opposite specimen endface as a detector of the thermal phonons passing through the specimen. The specimen was disposed vertically in a cryostat with the heater at the upper end. The measurements were performed at a 1.6 K temperature. A sequence of three pulses, two of which Q_1 and Q_2 had an intensity from $5 \cdot 10^3$ to $6.3 \cdot 10^4$ kW/m², were delivered to the heater. The intensity Q_3 of the third (test) pulse was usually 200-1250 kW/m². Indeed, a pulse Q_3 of such intensity for a duration $\tau_3 = 100$–200 nsec could be considered a test since it does not cause helium boiling. This is confirmed by the fact that, firstly, under preliminary heating the signal from the pulse Q_3 is magnified and this magnification is independent of the quantity Q_3 for small delay times. Secondly, without preliminary heating the signal shape is rectangular, i.e., duplicates the shape of the current pulse at the heater. The rise of the signal trailing edge, indicating the beginning of liquid helium boiling on the heater surface [1, 2] is observed only for times $\tau_3 > 400$ nsec.

The intensity $Q = U^2/(RS)$, the duration τ of each pulse, the delay time t_{12} between the first and second and t_{23} between the second and third pulses could be regulated independently.

The signal amplitude from the test pulse was measured experimentally with and without preliminary heating. The signal intensities from the first two pulses could be more than two orders of magnitude greater than the test pulse signal at the bolometer. Hence, for delay times t_{23} less than three-four transit times of the transverse phonons through the specimen, the signal from the third pulse is superposed on a strong diffusion background or on powerful ballistic signals from the first pulses. Consequently, in order to track the change in signal shape and intensity from the test pulse, it was recorded as follows. The pulses Q_1 and Q_2 were delivered to the heater at the frequency F while the pulse Q_3 was delivered at the frequency F/2. After magnification the signal from the bolometer was delivered to a stroboscopic oscilloscope triggered at the frequency F. A differential amplifier whose inputs were also commutated at the frequency F was connected to the analog output of the oscilloscope. This permitted attenuation of the signal from the first two pulses by approximately 60 dB, and in practice only the signal from the third pulse was recorded on the X–Y plotter. As a rule all the measurements were made for L-mode ballistic phonons. The response time of the recording system was determined mainly by the fast-response of the bolometer and did not exceed 30 nsec. The pulse repetition rate was selected from the condition $F^{-1} \gg t_{12} + t_{23}$ so that the signals being observed would be independent of F. Moreover, a high pulse repetition rate could result in the specimen temperature T_0 being different from the helium bath temperature T_{He}. This was controlled easily by changing the position of the bolometer working point on the superconducting transition curve. It turns out that it is sufficient to take a frequency $F \leq 1$ kHz so that $T_0 - T_{He} < 0.01$ K. All the experimental data are presented below for F = 100 Hz.

We first present results referring to the case when preliminary film heating is realized by just one powerful current pulse ($Q_1 = 0$). Displayed in Fig. 1 is the experimental dependence of the gain coefficient $K = J/J_0$ on the delay time t_{23} between the preliminary pulse Q_2 and the test pulse Q_3. Let us note that the quantity $K(t_{23} \approx 0)$ is independent of the intensity Q_3 and the duration τ_3 of the test pulse [1]. The curves in Fig. 1 with up to 10% deviation are described by the empirical formula

$$K = \frac{J}{J_0} = K\left(Q_2 \sqrt{\tau_2/t_{23}}\right) = \frac{5{,}6}{1 + 4{,}6 \exp\left(-AQ_2 \sqrt{\tau_2/t_{23}}\right)}, \tag{1}$$

where τ_2 is the preliminary pulse duration and $A = 0.086$ (kW/m²)$^{-1}$.

Here and henceforth, the time interval between the trailing edge of one pulse to the leading edge of the next is taken as the delay time between pulses, particularly t_{23}. It follows from Fig. 1 and (1) that the influence of preliminary heating on the test signal amplitude is felt all the more, the greater the duration and intensity of the pulse Q_2.

For the case when two current pulses are delivered preliminarily to the heater, the dependence of K on t_{23} is presented in Fig. 2 (curve 1). Displayed there for comparison is the

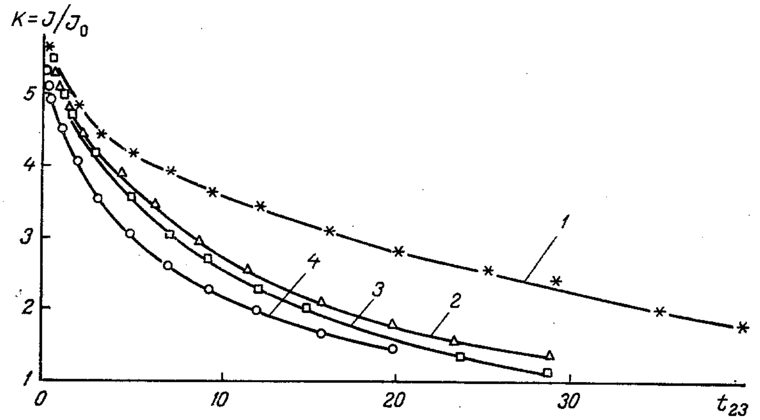

Fig. 1. Dependence of the test pulse gain coefficient $K = J/J_0$ on the delay time for different stimulating pulse parameters: 1) $Q_2 = 2.5 \cdot 10^4$ kW/m², $\tau_2 = 100$ nsec; 2) $1.16 \cdot 10^4$ and 200; 3) $2.5 \cdot 10^4$ and 40; 4) $1.16 \cdot 10^4$ and 100. t_{23}, μsec.

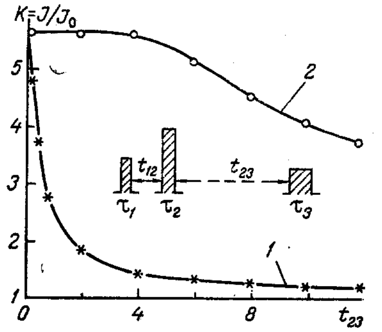

Fig. 2

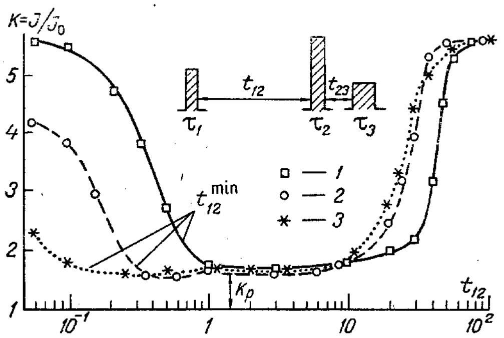

Fig. 3

Fig. 2. Influence of additional current pulses on the dependence of $K = J/J_0$ on the delay time t_{23}: 1) $Q_1 = 1.7 \cdot 10^4$ kW/m², $\tau_1 = 40$ nsec, $t_{12} = 0.3$ μsec, $Q_2 = 6.3 \cdot 10^4$ kW/m², $\tau_2 = 100$ nsec; 2) $Q_1 = 0$, $Q_2 = 6.3 \cdot 10^4$ kW/m², $\tau_2 = 100$ nsec.

Fig. 3. Dependence of $K = J/J_0$ on the delay time t_{12} for $\tau_1 = 40$ nsec, $Q_2 = 6.3 \cdot 10^4$ kW/m², $\tau_2 = 100$ nsec, $t_{23} = 5$ μsec, $\tau_3 = 200$ nsec, $Q_3 = 1.25 \cdot 10^3$ kW/m² and different Q_1: 1) $2.6 \cdot 10^4$ kW/m²; 2) $1.7 \cdot 10^4$; 3) $1.15 \cdot 10^4$.

corresponding dependence for $Q_1 = 0$ (curve 2). It is seen that both curves start from one point for $t_{23} = 0$, but this is observed only for $Q_2 > 10^4$ kW/m². For these intensities, even for $Q_1 = 0$, the second pulse causes helium boiling along the whole film surface, consequently, the whole heater surface is covered by vapor for zero delay time ($t_{23} = 0$) and the test signal amplitude is maximal. As is seen from Fig. 2, the most interesting fact is that the drop time of the test signal amplitude for preliminary film heating by two pulses is approximately 1 μsec while for $Q_1 = 0$ the drop time exceeds 20 μsec. The difference is greater than by an order of magnitude.

Therefore, if a pulse Q_1 several times smaller in intensity or duration than the powerful pulse Q_2 is delivered before it to the heater, then the test pulse Q_3 generation of phonons in the specimen attenuates rapidly. Such attenuation is observed not for all delay times t_{12} between the preliminary pulses Q_1 and Q_2. Indeed there is no attenuation for $t_{12} = 0$ and $t_{12} = \infty$ since these cases are equivalent to single-pulse heating (the influence of the first pulse vanishes for $t_{12} = \infty$ and a disturbance from only Q_2 is felt by the test signal amplitude). Presented in Fig. 3 is the dependence of K on t_{12} for a fixed delay $t_{23} = 5$ μsec. It is seen that the presence of a minimum is characteristic for all the curves. This minimum is in the shape of a plateau of around 10 μsec width with beginning at the point t^{min}. The magnitude of the signal on the plateau is independent of Q_1 (for $Q_1 > 10^4$ kW/m²). The experimentally measured values of t_{12}^{min} and the gain coefficient on the plateau K_p are presented in the table for different values of Q_1 and Q_2. Also given here is the magnitude of the gain coefficient

TABLE 1. Experimental Values of t_{12}^{min}, K_p and K* for Different Preliminary Heating Pulse Parameters (τ_1 = 40 nsec)

Q_1, 10^4 kW/m²	Q_2, 10^4 km/m²	τ_2, nsec	t_{12}^{min}, µsec	K_p	K^*
0,625	3,23	40	0,015—0,02	1,08	3,16
1,32	3,23	40	0,5—0,6	1,08	3,83
2,07	3,23	40	2,1	1,43	3,83
2,07	2,07	40	1,4—1,6	1,38	3,76
2,07	4,65	40	1,1—1,2	1,43	3,84
2,07	2,07	100	1,1	1,33	4,15
2,07	3,23	100	0,8	1,43	3,21

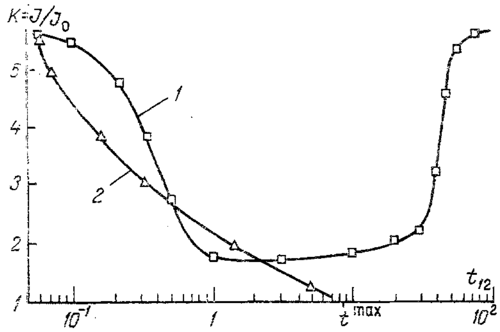

Fig. 4. Comparison of the time dependences of the gain coefficient K of the test pulse for two and one pulse preliminary heating (Q_3 = $1.25 \cdot 10^3$ kW/m², τ_3 = 200 nsec, Q_1 = $2.6 \cdot 10^4$ kW/m², τ_1 = 40 nsec): 1) Q_2 = $6.3 \cdot 10^4$ kW/m², τ_2 = 100 nsec, t_{23} = 5 µsec 2) Q_2 = 0, the pulse Q_3 is delivered in place of Q_2 (t_{23} = 0, i.e., $t_{12} = t_{13}$).

K* for the test pulse signal delivered in place of the second pulse (Q_2 = 0) at the time $t_{13} = t_{12}^{min}$. The test pulse intensity and duration were Q_3 = 830 kW/m², τ_3 = 100 nsec.

Moreover, it can be noted from Figs. 1 and 3 that if the test pulse is delivered in place of the pulse Q_2, then the pulse Q_1 will already not exert any influence on the test signal amplitude after $t_{13} = t_{12} \geq t^{max}$ (the quantity t^{max} depends on the first pulse parameters). If $Q_2 \neq 0$, then even for delays six-seven times greater than t^{max}, the pulse Q_1 causes a diminution in the test signal amplitude. This is illustrated by the curves presented in Fig. 4.

DISCUSSION OF THE RESULTS

Our comprehension of the results obtained is based on the assumption partially verified in [1] that the test pulse signal amplitude magnification is caused by diminution of the heater contact area with the liquid helium. It is important to the description of the experiment that a unique correspondence exist between the test pulse signal amplitude and the heater contact area with the liquid. Let us establish this connection.

The Joulean power U^2/R is liberated upon delivering a test current pulse or voltage U to a metallic film of resistance R. This heat results in thermal phonon radiation in the helium and the specimen

$$\frac{U^2}{R} = W_{He} + W_0. \tag{2}$$

Here W_{He} and W_0 are the heat fluxes in the helium and specimen, respectively. The signal being observed in the specimen is $J \sim W_0$ in the absence of thermal phonon scattering. It should be taken into account in the derivation of an analytic expression for W_0 that preliminary film heating results in boiling of the liquid helium at its interface with the film. Consequently, a partof the heater of area S_g is covered with vapor up to the time of test pulse delivery. The remaining part, whose area is $S_f = S - S_g$ delimits the liquid helium. The vapor-covered domain is heated to the temperature T_g during action of the test pulse while the domain in contact with the liquid is heated to T_f ($T_f < T_g$). Heating is realized, respectively, in the times τ_g and τ_f, that agree with the phonon exit times from the film domains under consideration [3]:

$$\tau_g = \frac{4d}{\bar{l}_o \bar{v}}, \quad \tau_f = \frac{4d}{(\bar{l}_o + \bar{l}_{He})\, \bar{v}} .$$

Here $\bar{v}$ and $\bar{l}_{o(He)}$ are the phonon velocity and transmission coefficient from the heater to the specimen (liquid helium) averaged relative to polarizations:

$$\bar{v} = (v_L^{-2} + 2v_T^{-2})/(v_L^{-3} + 2v_T^{-3}) \simeq v_T ,$$

$$\bar{l}_{o(He)} = (l^L_{o(He)} v_L^{-2} + 2l^T_{o(He)} v_T^{-2})/(v_L^{-2} + 2v_T^{-2}),$$

where v_j and $l^j_{o(He)}$ are the velocity and transmission coefficient of a mode j phonon from the heater to the specimen (liquid helium). For the copper heater we used that is deposited on a sapphire substrate, we have [1]: $\bar{l}_{He} = 0.62$, $\bar{l}_o = 0.134$, $\bar{v} = 2.39 \cdot 10^3$ m/sec. Consequently, $\tau_g = 0.75$ nsec, $\tau_f = 0.13$ nsec. It is seen from the estimates presented that heating is realized in the time <1 nsec after the beginning of pulse action, which is much shorter than its duration $\tau_3 \approx 100$ nsec. Therefore, the following stationary distribution is already established at the beginning of pulse action: the temperature equals T_g and T_f, respectively, in the heater domain covered by the vapor and in contact with the liquid helium, and changes between these values in a narrow transition layer. The thickness of this layer is determined by the thermal diffusivity χ of the copper and equals $\sqrt{\chi\tau_g} + \sqrt{\chi\tau_f}$. The values of χ for T = 6 K fluctuate between $2.9 \cdot 10^{-2}$ and 4.88 m^2/sec [4] for copper of different degrees of purity. In our case, electrotechnical copper, not distinguished by special purity, was used as initial material for the heater. Consequently, the value $\chi = 1 \cdot 10^{-1}$ m^2/sec is used for the estimate. Then the transition layer thickness will be $1.2 \cdot 10^{-5}$ m, which is much less than the heater size, and we shall henceforth consider it zero. Therefore, the heat flux W_o in the specimen during pulse action goes from two heater domains having a different temperature which does not change during the pulse action:

$$\begin{gathered} W_o = W_o^{(f)} + W_o^{(g)} , \\ W_o^{(f)} = \bar{l}_o \sigma (T_f^4 - T_o^4)(S - S_g), \\ W_o^{(g)} = \bar{l}_o \sigma (T_g^4 - T_o^4) S_g. \end{gathered} \tag{3}$$

Here σ is the analog of the Stefan-Boltzmann constant

$$\sigma = \frac{\pi^2 k_B^4}{120\hbar^3}(v_L^{-2} + 2v_T^{-2}).$$

The usual formula for the heat flux between bodies with different temperatures [5] was used in writing (3). It was also taken into account that the specimen temperature does not change during pulse action and remains equal to its initial value T_o since the mean free path of the thermal phonons radiated by the film is greater than the specimen size and the phonons are propagated therein mainly ballistically.

We later need an expression for the heat flux from the heater to the helium W_{He}. It is comprised of fluxes in the gaseous $W_{He}^{(g)}$ and fluid $W_{He}^{(f)}$ helium. By using empirical values of the heat transfer coefficient [6] in helium during film boiling, it is easy to show that the heat flux in the gas is two orders of magnitude less than in the fluid, consequently, $W_{He} \approx W_{He}^{(f)}$. As in [1, 7], we shall consider that the expression for $W_{He}^{(f)}$ has the form

$$W_{He}^{(f)} = \frac{\bar{l}_{He}}{\bar{l}_o} W_o^{(f)} . \tag{4}$$

Then the following equations are valid

$$\frac{U^2}{R}\,\frac{S - S_g}{S} = W_{He}^{(f)} + W_o^{(f)} = \left(1 + \frac{\bar{l}_{He}}{\bar{l}_o}\right) W_o^{(f)} , \quad \frac{U^2}{R}\,\frac{S_g}{S} = W_o^{(g)}. \tag{5}$$

The Joulean power being liberated in the heater domain covered by the liquid helium is on the left in (5) (the left equation) and in the domain covered by the vapor (right equation). Because of its smallness, the heat flux in the gaseous helium is omitted from the right equation. Taking (3) and (5) into account, the following expression can be obtained for the test signal amplitude

$$J \sim W_0 = \frac{U^2}{R} \frac{\bar{l}_0 + \bar{l}_{\mathrm{He}}(S_g/S)}{\bar{l}_0 + \bar{l}_{\mathrm{He}}}. \tag{6}$$

In the absence of preliminary heating, when there is no vapor on the heater surface, the expression for the heat flux in the specimen is obtained from (6) for $S_g = 0$

$$J_0 \sim W_0^{\circ} = \frac{U^2}{R} \frac{\bar{l}_0}{\bar{l}_0 + \bar{l}_{\mathrm{He}}}. \tag{7}$$

By using (6) and (7) the gain coefficient K can be obtained, i.e., the experimentally measured ratio of the test signal amplitudes with and without preliminary heating

$$K = \frac{J}{J_0} = 1 + \frac{\bar{l}_{\mathrm{He}}}{\bar{l}_0} \frac{S_g}{S}. \tag{8}$$

We should here examine the test pulse concept in more detail. The test pulse intensity for a given duration is constrained not only from above but also from below. The upper bound is necessary in order for S_g not to change noticeably during the pulse action, i.e., so no noticeable evaporation of the condensed helium would occur, and the lower bound so that S_g could be determined from the signal shape [1].

We have therefore succeeded in establishing a connection between the magnitude of the relative heater area S_g/S covered with vapor and the test signal being observed.

All the curves in Figs. 1-3 graphically describe substantially the time change in the relative heater area covered by gaseous helium. Moreover, in the case of preliminary heating by one pulse (see Fig. 1), an analytical dependence of S_g/S on the time can be obtained. Thus, for instance, by comparing (8) with the empirical dependence (1), we have

$$\frac{S_g}{S} = \frac{1 - \exp(-AQ_2 \sqrt{\tau_2/t_{23}})}{1 + \frac{\bar{l}_{\mathrm{He}}}{\bar{l}_0} \exp(-AQ_2 \sqrt{\tau_2/t_{23}})}. \tag{9}$$

It has here been taken into acount that the dependence (1) is obtained for a copper film deposited on a ruby specimen. The values of the thermal phonon transmission coefficients in liquid helium and the specimen, measured experimentally in [1] for this case, satisfy the relationship $\bar{l}_{\mathrm{He}}/\bar{l}_0 = 4.6$. A unique result follows from Fig. 1 and (9): upon heating a metallic film by one pulse the quantity S_g/S diminishes with time all the more slowly, the greater the intensity and duration of the heating pulse.

If still another powerful pulse Q_1 is delivered before Q_2, then the quantity S_g/S diminishes considerably more rapidly (curve 1 in Fig. 2). As is seen from Fig. 3, attenuation of the test pulse signal, and therefore, the rate of S_g/S diminution are maximal if the time t_{12} between the preliminary pulses become larger than a certain value $t_{12}^{\min}$. From this same figure it is seen that $t_{12}^{\min}$ depends on Q_1. This is seen from the table of Figs. 1 and 3. As follows from (8), equal S_g correspond to equal quantities K, i.e., after corresponding times $t_{12}^{\min}$ before the delivery of the second pulse, the heater areas $S_f = S - S_g$ covered by the liquid helium are mutually equal. It hence results that for an abrupt diminution in S_g it is necessary that the heater area S_f exceed a certain minimal value $S_f^{\min}$ before the delivery of the powerful pulse Q_2.

The reasons for the more rapid diminution of S_g/S for two-pulse preliminary heating as compared with the one-pulse mode are not clear. This is possibly associated with the hydrodynamic separation of the gaseoue blanket by the liquid helium, i.e., the fluid motion. Either thermal instability of the two-phase gas + liquid system or dynamic effects associated with the boiling of the liquid helium covering a part of the heater area after the first pulse [8, 9] might be the reason for this motion. It seems to us that the presence of $S_f^{\min}$ makes the latter reason most probable.

It is seen from Fig. 4 that the influence of heating on the test signal amplitude is conserved for two-pulse preliminary heating much longer than for the one-pulse mode. The test signal gain coefficient is K = 1 for such long delay times and one-pulse heating. Consequently, as follows from (8), $S_g = 0$, i.e., the whole heater area is covered by liquid helium up to the time of delivery of Q_2. Nevertheless, after the delivery of the second pulse S_g diminishes more rapidly than for $Q_1 = 0$. It is possible that boiling of the helium under the effect of the first pulse results not only in $S_g \neq 0$ but also produces long-lived stimulation in the fluid [10].

Therefore, by relating the change in test signal amplitude to the change in heater area covered by gaseous helium, a number of the results represented graphically in Figs. 1-4 is successfully comprehended. This is related to the difficulty in understanding the physical processesesin two-phase systems [8, 9].

In conclusion, let us note that a sequence of current pulses delivered to a metallic film results not only in boiling, as in the case of one pulse, but also to new unexpected effects.

NOTATION

Q_i, pulse intensity, W/m^2; τ_i, pulse duration, sec; t_{ij}, delay time between pulses, sec; S, heater area, m^2; d, heater thickness, m; R, resistance, Ω; U, voltage, V; F, pulse repetition rate, Hz; $T_{He(o)}$, liquid helium (specimen) temperature, K; K, test pulse signal gain coefficient; $J(J_0)$, amplified (unamplified) signal amplitude in relative units; $\tau_{f(g)}$, phonon flight time out of the corresponding heater domains, sec; χ, thermal diffusivity coefficient of the heater material, m^2/sec; $W_{o(He)}$, heat flux from the heater in the specimen (helium), W; $\bar{l}_{o(He)}$, phonon transmission coefficient from the heater into the specimen (helium); $\bar{v}$, phonon velocity in the heater, m/sec; σ, analog of the Stefan–Boltzmann constant, $W/(m^2 \cdot K^4)$; A, a constant $(W/m^2)^{-1}$; K_p is the minimal value of the trial pulse signal gain for a fixed delay t_{23}. K^*, gain coefficient of the test pulse signal delivered at the time $t_{13} = t_{12}^{min}$ for $Q_2 = 0$; t_{12}^{min}, delay time between the first and second pulses starting with which the signal gain coefficient is minimal for a fixed delay t_{23}; t^{max}, delay time between the powerful and test pulses, starting with which K = 1, sec; k_B, Boltzmann constant; $\hbar$, Planck constant. Subscripts; i, j, pulse number; f, g, heater domains delimiting the liquid and gaseoushelium; L, T, longitudinal and transverse modes, and the upper bar is averaged with respect to polarizations.

LITERATURE CITED

1. A. V. Golitsin, V. N. Lisin, B. M. Khabibulin, and A. M. Shegeda, Phys. Lett., 109, No. 9, 457-460 (1985).
2. V. N. Poroshin and B. A. Danil'chenko, Ukr. Fiz. Zh., 28, No. 8, 1191-1194 (1983).
3. I. B. Levinson, Physics of High Energy Phonons [in Russian], Moscow (1976), pp. 5-35.
4. M. P. Malkov, I. B. Danilov, A. G. Zel'dovich, and A. B. Fradkov, Handbook on the Physicotechnical Principles of Cryogenics [in Russian], Moscow (1985).
5. O. Weis, J. Phys., 33, No. 10, Suppl., C4/49-56 (1972).
6. S. W. Van Sciver, Cryogenics, 21, No. 9, 229-232 (1981).
7. B. A. Danil'chenko, V. N. Poroshin, and O. G. Sarbei, Pis'ma Zh. Éksp. Teor. Fiz., 38, No. 8, 386-388 (1983).
8. V. P. Skripov, Metastable Fluid [in Russian], Moscow (1972).
9. F. V. Bunkin and M. I. Tribel'skii, Usp. Fiz. Nauk, 130, No. 2, 193-237 (1980).
10. K. C. Rawling and Van der Suijz, J. Phys. Colloq., 39, NC6, 254-255 (1978).