Figure 4 also shows Seyfert's numerical calculations [3] and calculations from (3) for saturated He II based on the temperature dependence of the thermophysical parameters, which itself is based on m = 3.1 in (3) derived from stationary transfer. The variable-property calculations agree better with experiment than do Seyfert's.

We conclude that saturated He II responds to pulse loading as does underheated He II, but complete elucidation of the superheating mechanism under nonstationary conditions is at present lacking, so the conclusion can be extended only to the conditions used.

NOTATION

ρ, density; v, velocity; c, specific heat; T, temperature; τ, time; q, heat flux density referred to the cross section; x, longitudinal coordinate (along the axis); s, specific entropy; A(T), Görter–Mellink constant; m, exponent; k(T), temperature-dependent parameter; L, length; d, diameter; δ, thickness; h_K, Kapitsa conductivity coefficient; i, specific enthalpy; ΔE, energy referred to cross section; H, liquid level height. Subscripts: s, superfluid He II component; n, normal He II component; p, at constant pressure; b, parameters in He II bulk; λ, parameters at λ point; h, heater; cr, critical; st, stationary.

LITERATURE CITED

1. S. W. Van Sciver and O. Christianson, IEEE Trans. Magn. MAG-15, No. 1, 744-747 (1979).
2. R. Aymar, G. Claudet, C. Deck, et al., IEEE Trans. Magn. MAG-15, No. 1, 542-548 (1979).
3. P. Seyfert, N. Lafferranderie, and G. Claudet, Cryogenics, 22, 401-408 (1982).
4. J. C. Lottin and S. W. Van Sciver, Proc. Ninth Int. Cryogen. Eng. Conf. (1982), pp. 269-272.
5. L. Dresner, Adv. Cryog. Eng., 27, 411-419 (1982).
6. L. Dresner, Adv. Cryog. Eng., 29, 323-333 (1984).
7. S. Patterman, Superfluid Hydrodynamics [Russian translation], Moscow (1978).
8. D. White, O. D. Gonzales, and H. Jonston, Phys. Rev., 89, 593-597 (1953).
9. V. P. Belyakov, V. A. Shaposhnikov, V. V. Budrik, and N. M. Volkova, Izv. Akad. Nauk SSSR, Énerg. Transport, No. 1, 111-122 (1986).
10. D. Gentile and H. X. Francois, Cryogenics, 21, No 4, 234-237 (1981).
11. D. Gentile and H. X. Francois, Adv. Cryog. Eng., 27, 467-474 (1982).

INVESTIGATION OF THE HEAT TRANSFER OF CRYOGENIC FLUIDS IN A CENTRIFUGAL FORCE FIELD

N. M. Levchenko

UDC 536.24.08/023

Results of an experimental investigation of heat transfer during the boiling of cryogenic fluids (nitrogen, hydrogen, helium) in a large volume in a broad range of overloads and fluid levels above the heat eliminating surface are considered.

Different cryogenic fluids are utilized as coolants in many branches of the national economy. Knowledge of their heat transfer characteristics (heat elimination coefficients, boiling crises) permits maximal intensification of the working processes, elevation of the efficiency of installations and aggregates.

An analysis of results of an experimental investigation of the heat transfer of cryogenic fluids in a centrifugal force field (similarly to those elucidated in [1]) under the combined influence of pressure, overloads, and underheating on the heat-transfer intensity is represented in this paper.

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TABLE 1. Conditions for Conducting the Experiments

Fluid level h, m	Angular velocity ω, rad/sec	Overload $\eta = \frac{a_\omega}{g}$	Saturation T_{sH}, K	Saturation pressure, $P_{sH} \cdot 10^{-5}$ Pa	Fluid, temp. temp. $\bar{T}_f$, K	q_{cm}, W/m²
			Helium			
$1 \cdot 10^{-2}$	202	1259	4,585	1,398	4,59	11000
	216	1428	4,647	1,457	4,65	11000
	221	1500	4,652	1,479	4,68	11500
$7{,}2 \cdot 10^{-2}$	12,13	4,5	4,20	0,991	4,19	11500
	19,30	11,4	4,21	0,997	4,19	11800
	59,60	109,0	4,31	1,099	4,22	12000
	89,30	245,0	4,42	1,208	4,24	10500
	156,10	748,0	4,78	1,644	4,34	4000
	179,00	980,0	4,92	1,840	4,39	3700
	188,40	1090,0	4,99	1,946	4,42	1900
	205,00	1285,0	5,10	2,109	4,46	1800
	220,60	1495,0	5,20	2,273	4,47	2600
	222,00	1526,0	5,20	2,280	4,44	—
	225,00	1556,0	5,22	2,340	4,48	—
	238,00	1740,0	5,27	2,440	4,90	—
$18{,}5 \cdot 10^{-5}$	11,6	4,2	4,23	1,013	4,21	11000
	18,9	11,0	4,24	1,020	4,22	11000
	40,7	50,8	4,25	1,057	4,23	11000
	56,2	97,0	4,32	1,110	3,23	10600
	85,0	222,0	4,43	1,220	4,25	9650
	130,0	515,0	4,67	1,495	4,29	4200
	188,0	1082,0	5,04	2,027	4,35	1960
	218,0	1485,0	5,24	2,333	4,50	1600
			Hydrogen			
$1 \cdot 10^{-2}$	0	1,0	20,36	1,000	20,37	—
	10,2	3,2	20,37	1,005	20,38	—
	17,5	9,4	20,38	1,007	20,25	—
	57,6	101,7	20,47	1,034	20,28	—
	180,5	1000,0	21,02	1,217	20,30	—
			Nitrogen			
$1 \cdot 10^{-2}$	0	1,0	77,33	1,01	77,3	—
	11,6	4,2	77,34	1,01	77,2	—
	17,5	9,4	77,35	1,01	77,2	—
	18,2	10,2	77,36	1,01	77,2	—
	57,0	100,0	77,85	1,07	77,5	—
	90,0	248,0	78,67	1,17	77,6	—
	151,0	700,0	80,86	1,52	77,8	—
	180,5	1000,0	81,82	1,60	78,4	—
	255,0	2000,0	85,22	2,37	79,5	—

The method of conducting the experiment and the construction of the installation are described in [2, 3]. The experiments were conducted on helium, nitrogen, and hydrogen for different fluid levels above the heat eliminating surface. The endface of a copper cylinder of $1.5 \cdot 10^{-2}$ m diameter and $0.5 \cdot 10^{-2}$ m altitude was used as the heat eliminating surface.

The fluid level above the heat-eliminating surface was maintained constant during the experiment by a continuous supply of fluid to the working capacity. A film boiling mode was obtained on the heat eliminating surface before the beginning of each experiment, i.e., the heat eliminating surface "was run in" (such "running in" was not realized successfully with nitrogen since the heaters of the heat-eliminating surface overheated for $q \simeq q_{cr1}$). After "run-in" the thermal flux was reduced and the necessary angular velocity of the installation rotor was set up (ω = const). A given heat flux was supplied to the heater of the heat-eliminating surface for a constant mass flow rate of fluid. After stationary conditions are reached, values of the temperature and heat flux were determined. Then the heat flux was changed and the process repeated until $q = q_{cr1}$. The time to reach stationary conditions on the heat eliminating surface diminished as the heat flux increases but was not less than 3 min. The conditions for conducting the experiments are given in the table.

The heat elimination intensity was determined from the experimental dependences $q(\Delta T)$ and $\alpha(q)$, in which the temperature heads ΔT_{sH} and $\Delta \bar{T}_f$ were found, respectively, from the relationships $\Delta T_{sH} = T_f - T_{sH}$ and $\Delta \bar{T}_f = T_n - \bar{T}_f$. Attempts to generalize data about the heat elimination coefficients calculated by means of $\Delta \bar{T}_f$ result, as remarked in [4], in formulas mainly suitable for just the conditions of this experiment.

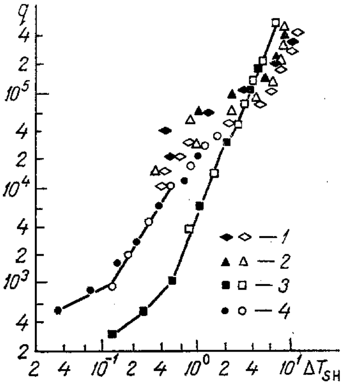

Fig. 1

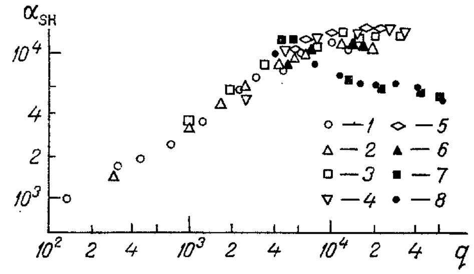

Fig. 2

Fig. 1. Dependence of the heat flux, q, W/m² on the temperature head ΔT_{sH}, K for cryogenic fluid boiling, $h = 1 \cdot 10^{-2}$ m (open points — increase, dark points — diminution in q): 1, 2) nitrogen, η = 1000 and 700, respectively; 3) hydrogen, η = 1000; 4) helium, η = 1428.

Fig. 2. Dependence of the heat elimination coefficient α_{sH}, W/(m²•K) on the heat flux q for helium boiling; $h = 7.2 \cdot 10^{-2}$ m; 1) η = 4.52; 2) 11.4; 3) 109; 4) 245; 5) 748; 6) 980; 7) 1090; 8) 1285.

Measurements of the temperature distribution in the fluid layer above the heat eliminating surface [5] show that elevation of the fluid level and the overload $\eta = a_\omega/g$ (where $a_\omega = \omega^2 R$) contributes to an increase in the underheating $\vartheta = T_s - \overline{T}_f$, whose magnitude depends weakly on the heat flux and remains practically constant even for $q \gg q_{cr1}$, i.e., independently of the magnitude of the heat flux the fluid above the heat eliminating surface will always be underheated to the saturation temperature T_{sH}. The expression of the heat elimination coefficients in terms of ΔT_{sH} obtained for elevated overloads (α_{sH}) permits comparing them with values of α_s for ordinary conditions ($\eta = 1$). Typical experimental dependences $q(\Delta T_{sH})$, obtained in a centrifugal force field, are represented in Fig. 1 for different fluids for $h = 1 \cdot 10^{-2}$ m above the heat elimination surface. The dependences $q(\Delta T_{sH})$ have the traditional S shape, which is more clearly defined for nitrogen which is probably associated with the presence of the greatest underheating (ϑ = 3 K at $\eta \geq 7 \cdot 10^2$). Because of the low fluid level and small helium and hydrogen densities, the underheating in these fluids under the given experiment conditions is practically nonexistent and did not exceed the accuracy of the temperature measurement. The heat elimination coefficients expressed in terms of ΔT_{sH} is not expressed much higher in terms of $\Delta \overline{T}_f$ and almost does not change as the overload grows.

The heat elimination intensity during the boiling of helium and hydrogen is practically independent of the heat flux direction (increase or decrease), however, the heat elimination hysteresis occurred during nitrogen boiling, which is associated, as was mentioned earlier, with the impossibility of "running-in" the heat eliminating surface.

The small growth in the heat elimination intensity as the overload increases in the developed boiling mode (for all the fluids being investigated [1]) for a $h = 1 \cdot 10^{-2}$ m fluid level above the heat eliminating surface is apparently associated with the additional turbulization of the fluid that occurs because of its continuous delivery to the working capacity. Such a rise in the heat elimination intensity in the developed nucleation boiling mode is not observed for high fluid levels ($h = 7.2 \cdot 10^{-2}$ and $18.5 \cdot 10^{-2}$ m) [1].

A significant rise in the heat elimination level would occur in the convective domain (for $q < q_{nb}$) for all the fluids investigated and their levels above the heat eliminating surface [1]. A comparison of the dependences $\alpha_{sH}(q)$ for helium (for $\eta > 1$) with the dependences $\alpha_s(q)$ (for $\eta = 1$) [1] shows that for identical or nearby pressures the boiling curves obtained in the earth's gravity field almost always intersect (or have a tendency to intersect) at two points with the boiling curves obtained for $\eta > 1$. For η = 10-100 overloads the intersection occurs at the point with $q \approx (4\text{-}6) \cdot 10^3$ W/m² and is related to the increase in underheating that contributes to the delay in the beginning of fluid boiling. The second point of intersection of the boiling curves in the precrisis domain is ordinarily in the domain of high q values. This intersection is associated with the usual diminution in the slope of the dependences in the precrisis domain, while the values of q at the point of intersection are still substantially less than the quantity q_{cr1} for boiling curves in a centrifugal force field. Dependences of the heat elimination coefficients α_{sH} on q have a less regular form for overloads $\eta \geq 10^3$, however, the exposed tendencies are conserved although the points of intersection are indeed shifted towards higher heat fluxes [1].

As the fluid level increases the points of intersection of the dependences $\alpha_s(q)$ with the dependences $\alpha_{sH}(q)$ shift for $\eta \geq 10^3$ towards lesser heat fluxes, which is related to the diminution in the values of q_{cr1} as $P_{sH} \to P_k$ [1].

Analysis of the experimental dependences $\alpha_{sH}(q)$ obtained in broad heat flux and overload ranges shows that the heat elimination intensity grows as the heat flux increases and is practically independent of the overload. Because of the growth of the quantities q_{nb} and q_{cr1} the boiling curves $\alpha_{sH}(q)$ shift towards higher heat fluxes as the overload increases. The slope of the dependences $\alpha_{sH}(q)$ for $h = 1 \cdot 10^{-2}$ remains almost unchanged up to $q = 6 \cdot 10^3$ W/m², however, for higher heat fluxes the slope of the dependences $\alpha_{sH}(q)$ start to diminish. The same diminution in the slope of the dependences $\alpha_{sH}(q)$ was observed for $h = 7.2 \cdot 10^{-2}$ and $18.5 \cdot 10^{-2}$ m for heat fluxes $q > (3\text{-}4) \cdot 10^3$ W/m². The change in slope of the dependences $\alpha_{sH}(q)$ for high q would also hold even for nitrogen [6] in cylindrical heaters for $h = 5 \cdot 10^{-2}$ and $10.3 \cdot 10^{-2}$ m above the heat eliminating surface.

It is noted in [7] that a change in the slope of the boiling curves is apparently associated with the formation of film boiling foci on a certain part of the heat eliminating surface, which contribute to the growth of the mean temperature of the heat eliminating surface and therefore also to the diminution of the heat elimination intensity.

For the high fluid levels and high overloads for which the pressure at the level of the heat eliminating surface approaches the critical or becomes greater than the critical $P > P_c$, the dependences $\alpha_{sH}(q)$ changes its slope radically, which can be either positive or negative (see Fig.2). The heat elimination intensity in this case drops strongly as the heat flux grows (the dark points in Fig. 2). For $P > P_c$ a pseudocritical temperature that was determined by means of the maximum specific heat of helium was used as the characteristic temperature in place of T_{sH}.

It is often important to know directly the magnitude of the temperature on a heat eliminating surface for a given heat flux. The dependences $\alpha_{sH}(q)$ are represented in the form $T_H(q)$ for this purpose.

Shown in Fig. 3 are typical dependences $T_H(q)$ obtained for the fluid level $h = 7.2 \cdot 10^{-2}$ m for identical or nearby saturation pressures. The temperature of the heat eliminating surfaces in the heat flux intervals $q_{cr1}(\eta = 1) \leq q \leq q_{cr1}(\eta > 1)$ increases and significantly exceeds not only the temperature of the ultimate fluid overheating T_{uo} for a given saturation pressure, but also the critical fluid temperature T_k. Such an excess of the temperature of the heat eliminating surface above T_k can, as was already noted in [7], be explained by the coexistence of film and nucleation boiling modes on the heat eliminating surface. The occurrence of a mixed boiling mode can also occur under ordinary condtiions ($\eta = 1$), for instance, on heat eliminating surfaces with a low heat conducting surface [8, 9], on heat eliminating surfaces from low heat conductive materials [10], and on plane heat eliminating surfaces having low thickness. It is noted in [11] that such a mode is also characteristic for high saturation pressures, i.e., as $P_s \to P_k$. In practice, the wall temperature of the heat eliminating surface was always higher than the ultimate overheating temperature T_{uo} for q/q_{cr1}, and sometimes even higher than T_k. An analogous rise in the temperature of the heat eliminating surface is also detectedina centrifugal force field, as is seen from the results of this paper and [7].

Of the parameters listed in [8-11] that contribute to the origin of a mixed boiling mode, the thickness of the heat eliminating surface ($\delta = 0.5 \cdot 10^{-2}$ m), which remained invariant in all the tests, was taken as such a parameter in this paper. The hydrostatic pressure of a fluid column which increased its underheating and depended on the overload, was another parameter contributing to the origination of a mixed boiling mode, i.e., those parameters that exert considerable influence on the hydrodynamics of the vapor phase during boiling were varied in the experiments performed.

Analysis of the microcharacteristics of the nucleate boiling process in a centrifugal force field, performed in [12], shows that the overload growth contributes to diminution of the separation radii of the bubbles R_d and the density of the vapor formation centers **z**. The frequency of vapor bubble separation f grows here. From an analysis of the boiling process

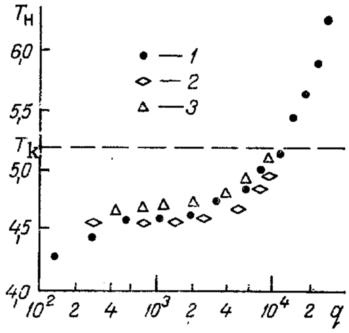

Fig. 3. Dependence of the temperature of the heat-eliminating surface T_H, K on the heat flux q for helium boiling, h = 7.2• 10^{-2} m: 1) η = 109; P_{sH} = 1.09•10^5 Pa, 2) η = 1; P_s = 1.05•10^5 Pa; 3) η = 1; P_s = 1.26•10^5 Pa.

microcharacteristics it can be assumed that desiccation of a fluid microlayer under one or several vapor bubbles resulting in replacement of the nucleation by the film boiling mode for η = 1 is not sufficient for an analogous replacement of the boiling modes in a centrifugal force field because of the substantial diminution of R_d with the growth of the overload ($R_d \sim \eta^{-0.3}$). The small dimensions of the film boiling foci being formed in the heat flux interval $q_{cr1}(\eta = 1) \leq q \leq q_{cr1}(\eta > 1)$ contribute here to an increase in the mean temperature of the heat eliminating surface, ordinarily measured integrally by one or several temperature sensors that are mounted within the heat-eliminating surface. As the heat flux increases the quantity of film boiling foci growsand a smooth transition into film boiling occurs, i.e., for η > 1 the heat elimination crisis sets in when the fine film boiling foci start to merge into coarser foci. According to estimates [12], the passage from the mixed to the film boiling mode can occur if and only if the area of the heat eliminating surface occupied by the film boiling foci reaches 40%. The significant diminution of the interphasal wavelength boundary λ during film boiling [13] contributes to the formation of fine film boiling foci

$$\lambda = 2\pi \sqrt{\frac{\sigma}{q(\rho_l - \rho_v)}}. \tag{1}$$

An estimate of the value of λ by means of (1) for different fluids shows that as the overload grows the distances between the bubbles being separated from the vapor film diminish and therefore, the size also diminishes of the bubbles that separate from the vapor film, the hydrodynamic pattern of the film boiling mode (η >> 1), is here outwardly similar to the nucleate boiling mode under ordinary conditions (η = 1), as visual observations show. The high values of the heat eliminating surface temperature $T_H > T_{uo} - T_k$ in the range $q_{cr1}(\eta = 1) \leq q \leq q_{cr1}(\eta > 1)$ and the significant increase in the heat elimination intensity of film boiling with the overload growth [14, 15] qualitatively confirm the hypothesis on the existence of a mixed boiling mode.

Taking such a hypothesis, we find the boundary of the passage from pure nucleate boiling to mixed boiling in the overload interval investigated. The magnitude of the heat flux at which the beginning of film boiling foci formation occurs q_{cm} was found for a given overload bytheintersection of the dependence $T_H(q)$ with the critical temperature T_k.

The values of q_{cm} obtained by such a method for each overload and liquid helium level above the heat-elimination surface did not exceed the temperature T_k for nitrogen and hydrogen in the overload range investigated, i.e., the mixed boiling mode was not observed. This is associated with the fact that for h = 1•10^{-2} m the saturation pressure at the level of the heat eliminating surface did not exceed 3•10^5 Pa, while a further rise in the heat flux was constrained by the possibilities of the supply source. The absence of a mixed boiling mode is also seen graphically from the dependences $\alpha_{sH}(q)$ represented in Fig. 4, whose slope remained unchanged in all the overload and heat flux ranges investigated. However, a mixed boiling mode occurred [6] for high liquid nitrogen levels above the heat elimination surface. Thus, for h = 5•10^{-2} and 10.3•10^{-2} m there already was no sharp transition from nuclear to film boiling for η > 10^3. The temperature of the heat eliminating surface was here above T_{uo} and sometimes exceeded even T_k.

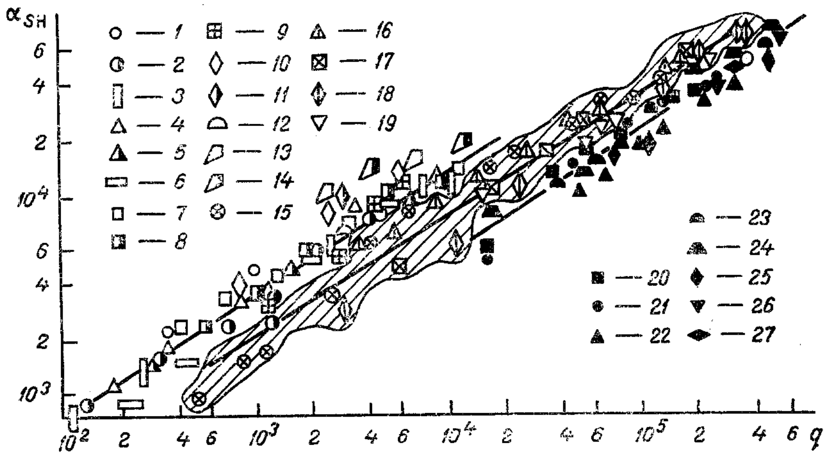

Fig. 4. Dependence of the heat elimination coefficient α_{sH} on the heat flux q during cryogenic fluid boiling, helium; h = 1·10⁻² m, 1) η = 3.4; 4) 10; 7) 100; 10) 1020; 13) 1259; 14) 1428; h = 7.2·10⁻² m; 2) η = 4.5; 5) 11.4; 8) 109; 11) 980; h = 18.5·10⁻² m; 3) η = 4.2; 6) 11; 9) 97.1; 12) 515; 1, 4, 7, 8); data [12]; hydrogen: h = 1·10⁻² m, 15) η = 1; 16) 3.2; 17) 9.4; 18) 102; 19) 1000; nitrogen: h = 1·10⁻² m; 20) η = 4.2; 21) 9.4; 22) 10.2; 23) 100; 24) 248; 25) 700; 26) 1000; 27) 2000.

Extension of the test data on heat elimination during nucleate and mixed boiling modes of cryogenic fluids in a centrifugal force field was performed by means of the relationship

$$\alpha_{sH} = Aq^n. \tag{2}$$

A computation by least squares of the proportionality coefficients A and the exponents n in the relationship (2) was performed for nucleate ($q_{nb} \le q \le q_{cm}$) and mixed ($q_{cm} \le q \le q_{cr1}$) boiling modes separately. Analysis of the values of A and n obtained shows that as the liquid helium level increases the exponent n grows negligibly (from 0.59 to 0.66), which is probably explained by the influence of the underheating that increases with the growth of the overload.

On the basis of the available test data, the heat elimination coefficient for nucleate boiling of helium on a plane heat eliminating surface in a centrifugal force field can be represented in the form the relationship (2) with A = 45.8 and the exponent n = 0.63 (Fig. 4, upper curve); for hydrogen A = 39.5 and n = 0.58 (middle curve), for nitrogen A = 20.6 and n = 0.6 (lower curve). The Student significance for the proportionality coefficients A was C_A = 5 on the average, while C_n = 18 for the exponent. The heat elimination coefficient in the helium mixed boiling mode can be represented in the form of the relationship (2) with A = 8.6 and n = 0.29. The Student significance for the proportionality coefficient is C_A = 3 while C_n = 7. Analogous processing of the data on nitrogen [6] in a tubular heat eliminating surface yields the following values: A = 4.6 and n = 0.33 for the Student significance C_A = 3 and C_n = 2.

The diminution in the exponent n for nitrogen [6] and helium qualitatively confirms the hypothesis that for large overloads contributing to the growth of hydrostatic pressure and underheating, a stable mixed boiling mode occurs on the heat eliminating surface.

LITERATURE CITED

1. N. M. Levchenko, Heat Elimination Intensity and Heat Transfer Modes during Cryogenic Fluid Boiling [in Russian], Preprint No. 13, Low-Temperature Physicotechnical Inst., Ukr., Acad. Sci., Kharkov (1986).
2. Yu. A. Kirichenko, N. M. Levchenko, S. M. Kozlov, et al., Cryogenic Electrical Machine Construction [in Russian], Kiev (1983), pp. 128-134.
3. Yu. A. Kirichenko, S. M. Kozlov, and N. M. Levchenko, Inzh.-Fiz. Zh., 42, No. 2, 207-213 (1982).
4. Yu. A. Kirichenko, Heat and Mass Transfer. VI. Probl. Repts. Sixth All-Union Conf. [in Russian], Pt. 1, Minsk (1980), pp. 146-160.

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

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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

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