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REPORT ON BOILING HEAT TRANSFER

By
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REPORT ON BOILING HEAT TRANSFER

By Novak Zuber*

Russian Literature on Boiling Heat Transfer

A brief compilation of Russian papers on boiling heat transfer and two phase flow was made because of the apparent lack of information in this country about the work reported by Russian researchers. Four days (two in the Library of Congress and two in the New York Public Library) were spent in assembling this bibliography. Because of the time factor only publications which are not available in the Los Angeles area were examined. Therefore, this report does not contain a complete list of Russian contributions in the above fields.

In addition to the Russian periodicals which are abstracted in the "Applied Mechanics Reviews" and the "Nuclear Science Abstracts", papers concerned with boiling heat transfer and two phase flow appear also in "Energeticheski Institut imeni G. Krzhizhanouskog - Izvestia" (abbreviated, Izvestia - ENIN) Akad. Nauk SSSR, (Libr. of Congr. TJ 297 A7); and in "Kotloturbostroenie", (Libr. of Congr. TJ 4 K6). Also, the Academy of Science (Akad. Nauk SSSR) and the Central Scientific Research Institut for Boilers and Turbines, Moscow and Leningrad (Tsentralnyi Naucno Isledovatel'skii Kotloturbinniy Institut; abbreviated Ts. K.T.I.) publish periodically monographs on recent advances in heat transfer and fluid dynamics. These monographs and periodicals generally are not available in this country; even the Libr. of Congress does not have a complete set of "Enin" and "Kotloturbostroenie".

Of the monographs on boiling heat transfer and two phase flow, the most often referred to book by Russian researchers is entitled, "Teplopredacha pri Kondenzatsii i Kipenii" (Heat Transfer by Condensation and Boiling) by S. S. Kutateladze, published by Mashgiz, 1954. The Libr. of Congr. has an outdated 1949 edition (QC 320 K84). The topics discussed therein are: drop and film condensation, evaporation, nucleate boiling, burnout stability, film boiling and two phase flow.

Another monograph, "Voprosy teploobmena pri izmeni agregatnogo sostoiania veshchestva" (On the Problem of Heat Transfer during a Change of Phase) was edited by S. S. Kutateladze and published by Goz. Enin Izd. Moscow, 1953 (Libr. of Congr. QC 320 K86). It contains papers by almost all Russian researchers working in the field. Among others there is a paper by Kutateladze on the burnout flux in pool boiling for subcooled alcohol; Kazakova reported recent burnout heat transfer rates for water in a pressure range up to 2800 psia. Borishanskii has two papers, one on dropwise condensation and another one on the minimum heat flow in film boiling of alcohol over a wide pressure range. Zysina-Molozhen presented data on the influence of pressure on the number of nucleating centers.

In view of the wave phenomena associated with two phase flow the monograph entitled, "The Exact Theory of Waves of Set Form on the Interface of a Liquid" by A. J. Nekrasov and published by Akad. Nauk SSSR Moscow, 1951 (Libr. of Congr. QA 927 N4) is of interest.

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The papers listed below are grouped according to the topics discussed. Only those are listed which, to the writer's knowledge, were not indexed in our literature and/or those which discuss topics whose investigation is presently underway or contemplated in several institutions of this country.

A. Bubble Dynamics and Nucleation

1. E. I. Nesis, "Boiling under Actual Conditions", *Zh. Tekh. Fiz.* **22**, 1506, 1952.
2. E. I. Nesis and Y. Frenkel, "Boiling of Gas Filled Liquid", *Zh. Tekh. Fiz.* **22**, 1500, 1952.
3. S. Derjagnin, "On the Dependence of the Contact Angle on the Microrelief of Roughness of a Wetted Solid Surface", *Doklady Akad. Nauk SSSR* v. 51, 5, p. 361, 1946.
4. N. N. Sirota, "On the Velocity of Formation of Nuclei of a New Phase and the Hysteresis of Transformation", *Doklady Akad. Nauk SSSR*, v. 51, 299, 1946.
5. Sh. G. Dzhandzhgava, "Investigation of the Formation of Vapor Bubbles on the Heating Surface", *Doklady Akad. Nauk SSSR*, **70**, 417, 1950.
6. L. M. Zisina, "Kinematographic Investigation of the Effect of Pressure on the Formation of Vapor Bubbles", *Tehn. Archiv. Ts.K.T.I.*, 1939.
7. L. M. Zisina, "Heat Transfer in Boiling Liquids", *Tehn. Archiv. Ts. K.T.I.*, 1941.
8. L. M. Zisina-Molozhen and S. S. Kutateladze, "On the Influence of Pressure on the Mechanism of Vapor Formation in Boiling Liquids", *Zh. Tekh. Fiz.* **20**, 110, 1950.

B. Boiling Heat Transfer

1. I. L. Tchernobilskii, I. M. Tanaiko, "Heat Transfer to Boiling Liquids in Pipes", *Zh. Tekh. Fiz.* **26**, 2317, 1956.
2. M. A. Styrikovich, "The Characteristic of the Process Inside Boiler Tubes at High Pressures", *Izvestia Akad. Nauk SSSR. OTd. Tekh. Nauk* No. 8, p. 1137, 1950.
3. S. M. Lukomskii and S. M. Kadorska, "Heat Transfer to Boiling Ethyl Alcohol in Pipes with Natural Circulation", *Izvestia A.N. SSSR O.T.N.* No. 9, 1306, 1951.
4. F. F. Bogdanov, Z. A. Miropolski, "Temperature Regime of Metal, Horizontal Vapor Generating Pipes for Boiling Organic Heat Carrier", *Izvestia A.N. SSSR O.T.N.* No. 7, 1952.
5. I. K. Margulova, "Experiments on Application of Radioactive Isotopes to Investigate the Purity of Steam in Semi-industrial High Pressure Boilers", *Izvestia A.N. SSSR* No. 8, 29, 1954.
6. S. S. Kutateladze, P. F. Karmilovich, "Expressions for the Temperature Gradient at the Boundary of Phase Separation in the Presence of the Process of Change of Aggregate State", *Sovetskoe Kotloturbostroenie* 1939, p. 191.
7. S. S. Kutateladze, L. M. Zysina Molozhen, "Experimental Investigation of Heat Transfer to Boiling Mercury", *Sovetskoe Kotloturbostroenie* 1939, p. 279.
8. G. N. Kruzhilin, "The Dependence of the Permissible Vapor Load of a Boiler on the Pressure", *Izvestia A.N. SSSR O.T.D.* No. 7, 1106, 1951.

C. Burnout Heat Flux

1. V. M. Borishanskii, "Study of Transition Forms of Boiling", *Tsentr.-Nauchno Isled. Ins. Kotloturbinnii, Kniga* 28, 1955.
2. M. A. Styrikovich, G. M. Poliakov, "On the Critical Heat Load to Boiling Liquids In Large Volumes", *Izvestia A.N. SSSR O.T.D.*, 5, p. 652, 1951.
3. L. S. Serman, N. G. Stoishin, V. G. Morozov, "Investigation of the Dependence of the Critical Heat Load on the Circulation", *Zh. Tekh. Fiz.* **26**, p. 2322, 1956.
4. V. S. Tchirkin, V. P. Iukin, "Critical Point in Heat Removal from Boiling Water Flowing Through an Annular Gap", *Zh. Tekh. Fiz.* **26**, p. 1542, 1956.

D. Two Phase Flow

1. V. K. Kozlov, M. A. Mologin, "On the Velocity of Rise and Hydraulic Resistance of Gas Bubbles in Liquids", *Izvestia, A.N. SSSR, O.T.N.*, No. 8, p. 1188, 1951.
2. S. S. Kutateladze, "Two Phase Flow in Tubes", *Kotloturbostroenie* 1947, No. 6, p. 17.
3. S. S. Kutateladze, "The Motion of Steam Liquid Mixtures in Pipes and Generalized Coordinates for its Analysis", *Kotloturbostroenie*, No. 2, p. 19, 1946.
4. M. A. Styrikovich, "Head Losses from Acceleration by Movement of Steam-Water Mixtures in Vertical Pipes", *Kotloturbostroenie* No. 4, p. 8, 1946.
5. M. A. Mologin, "Types of Flow, Limit, Critical Velocity in Vapor Gas Mixtures in Horizontal Pipes" *Izvestia A.N. SSSR O.T.N.*, No. 3, p. 126, 1956.
6. M. A. Mologin, "Wave Motion at the Interface of Two Phase Flow in a Horizontal Pipe", *Zh. Tekh. Fiz.* 26, No. 8, p. 1823, 1956.
7. L. S. Sterman, "Generalization of Experimental Data Concerning Bubbling of Vapor Through Liquids", *Zh. Tekh. Fiz.* 26, p. 1519, 1956.

Several general observations can be made concerning Russian papers. From the bibliography cited by Russian researchers it appears that they are very familiar with technical papers published in Germany, England and the United States. Thus, they draw from a larger source of information than their Western colleagues. Great emphasis is put on the analytical approach. Simple, inexpensive experiments are performed with the purpose of verifying theoretical models. Other simple experiments are designed with the purpose of analyzing the influence of one or two parameters only. The results of these experiments although without an immediate practical application shed a great light on the essence of the complex phenomenon. Thus, in the long run, these experiments become more important than those which at the moment are "practical". Some investigations which are at present carried out (or being considered) in this country have been performed and published in Russia. Examples are: the influence of pressure and surface on the number of nucleating centers, the sizes of bubbles departing from heating surfaces, the influence of subcooling in pool boiling at high pressures, the characteristics of two phase flows, etc.

In view of the above statements the following suggestions are proposed.

The contents of the latest editions of the two monographs by Kutateladze should be made available in this country.

Monographs published by the Academy of Science and the Ts. K.T.I. as well as the publications "Izvestia ENIN" and "Kotloturbostroenie" should be secured and abstracted.

A critical review of Russian investigations in boiling heat transfer and two phase flow should be made. Such a study combined with a review of the work of Western investigators should prevent duplication of research efforts and point out areas which need to be explored.