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ADVANCES IN HEAT TRANSFER*

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In recent years progress in nuclear, chemical, and aerospace engineering has stimulated interest in problems of heat transfer and hydrodynamics under various specific conditions: in the presence of changes of state of aggregation (boiling, ablation, transpiration), ionization and dissociation, near the critical state, in electric fields, in two-phase flows, etc. These are principal topics dealt with in the articles forming the collection "Advances in Heat Transfer," most of which were published as part of the proceedings of the Third International Heat-Transfer Conference (Chicago, 1966) and the 1965 and 1966 conferences of the American Heat Transfer and Fluid Mechanics Institute.

The first group of articles are concerned with the hydrodynamics of two-phase flows. The phase distribution and flow regimes are known to have an important influence on the rate of heat transfer and the pressure losses in a two-phase flow. A considerable mass of experimental data on the hydrodynamic structure of two-phase adiabatic and nonadiabatic flows has now been accumulated and attempts have been made to develop methods of classifying flow regimes. However, none of the methods can be considered entirely satisfactory, since they are largely based on a qualitaive description, for the most part on visual observations. In this connection the contributions of Hubbard and Dukler and Bergles and Suo, in which methods of determining flow regimes by measuring quantitative characteristics of the two-phase flow are proposed, are of undoubted interest. The former pair of authors took the pressure fluctuation spectral density distribution as such a characteristic, the latter pair determined the flow regimes on the basis of measurements of the electrical resistance of the two-phase mixture.

The next two articles are devoted to the problem of developing models and recommendations for calculating the true volumetric vapor content. In the article by Zuber, Staub, and Bijwaard formulas that take into account the vapor velocity and concentration profiles over the cross section and the local relative velocity between the phases are proposed. Moreover, in the case of systems not in thermodynamic equilibrium the liquid temperature profile is also considered. Satisfactory agreement with the experimental data is demonstrated. Petrick and Kudirki report the results of an experimental investigation to establish a relation between the phase distribution and the relative velocities in two-phase flows. The authors note a discrepancy between their data and the results of calculations based on the Bankoff and Zuber–Findlay models, whose physical basis they question.

Useful data are presented by Behar, Kurto, Rik, and Semeria on the tube boiling of liquids containing dissolved gases. It is shown that the presence of the gas intensifies the boiling heat transfer, there being no increase in pressure losses as long as the wall temperature is below the saturation temperature of the degasified liquid.

Chisholm proposes a theoretical basis for the empirical Lockhart–Martinelli relation for calculating the skin friction in a two-phase flow. The proposed model is unique in taking into account the presence of shear forces acting at the phase interface.

Janssen has made an experimental investigation of the still obscure problem of local resistances in a two-phase steam–water flow and gives an interesting visual flow pattern in the region of a contraction. Relations for calculating the pressure losses are proposed.

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A new method of measuring drop sizes in a dispersed two-phase conducting-fluid flow is described by Wicks and Dukler. This method is based on the closing by the drops of needle electrodes arranged a certain distance apart.

We still lack sufficient experimental data on the mechanism of destruction and drying of the liquid film in the dispersed-annular regime of two-phase flow. Hence the importance of the contribution by Macpherson and Murgatroyd, who describe an experimental investigation of this effect and an original method of electrical simulation of the process.

Todris and Rohsenow and Sato, Hayasido, and Motoda have investigated the burnout effect. The former have made a theoretical and experimental study of the relation between burnout and the heat flux distribution along the length of the channel. They confirm that axial nonuniformity may considerably reduce the channel. They confirm that axial nonuniformity may considerably reduce the critical heat load. The Japanese authors have experimentally determined the effect of fluctuations of the flow rate of a boiling two-phase medium on the critical heat load and have shown that the latter falls in the presence of fluctuations.

Uchida and Yamaguchi present certain results of an experimental investigation of the nucleate boiling of Freon-12 over a broad range of vapor contents. The authors make an interesting attempt to clarify the dependence of the heat-transfer mechanism on the vapor content of the flow with allowance for changes in the hydrodynamic flow regimes. Three regimes are considered: stratified flow, annular flow with a vapor core, and flow in mist form; empirical relations for calculating the heat-transfer coefficient are proposed.

Film boiling in horizontal tubes has been investigated by Kruger and Rohsenow. Especially interesting is their experimental apparatus, which, together with the main (measuring) tubular-metal section, includes an electrically heated transparent glass section for visual observations. The authors attempt to provide a theoretical basis for the experimental data.

Chang briefly discusses the inverse temperature profile effect detected by the author in a boiling two-phase potassium flow. The effect is important in connection with the design of nuclear power plants using liquid-metal heat transfer agents.

An interesting original theory of boundary layer turbulence is proposed by Blake. Although still being developed, this theory may prove useful for solving certain practical problems of hydrodynamics.

Tao's article is devoted to an analytic study of forced heat convection ducts of arbitrary cross section with allowance for viscous dissipation and internal heat release. Variational methods are employed. Interesting examples of the use of the proposed calculation techniques are supplied.

Benicio, Dussan, and Irvine solve a problem of complex convective–conductive–radiative heat transfer. Their data could prove very useful for developing spacecraft temperature control systems.

The neglected problem of heat-transfer instability near the critical point is the subject of an article by Cornelius and Parker, who have employed a Freon-114 experimental loop to investigate the mechanism and origin of flow-rate fluctuations and their effect on the heat-transfer coefficient.

At the end of the collection there are two papers dealing with missile and spacecraft heat shields. Vojvodich and Pope have investigated the effect on convective heat transfer in a high-temperature boundary layer of the presence of ablation products. Danberg, Winkler, and Chang have measured the skin friction, heat transfer, velocity profile, and other hypersonic boundary layer characteristics of a porous plate with air injection.

Moss and Grey briefly review the known methods of intensifying heat transfer in a gas and investigate the effect on heat transfer of steady and alternating electric fields.

Thus, the collection covers a broad range of topical heat-transfer problems. The contributions are original and of practical importance to a number of branches of modern technology. In general, the papers have been well chosen. It is possible to regret the failure to provide a more detailed introduction with a brief review of the essential problems and a comparison with the state of research in the same areas in the Soviet Union. Further publications along these lines, with contributions from both foreign and Soviet authors, would be welcome.