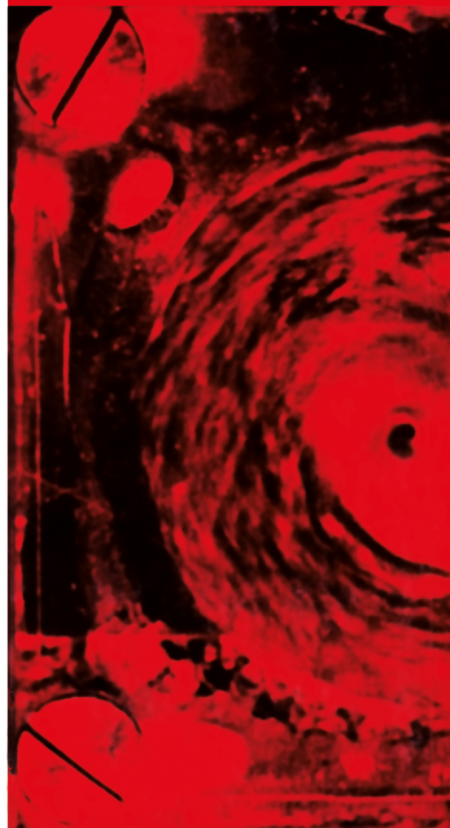
THEORY AND FUNDAMENTAL RESEARCH IN HEAT TRANSFER



Proceedings of the Annual Meeting of the American Society of Mechanical Engineers

Edited by
Professor J. A. CLARK
University of Michigan.

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OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
NEW YORK, NOVEMBER 1960

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PREFACE

THE Heat Transfer Division, having sponsored this Symposium at the 1960 Winter Annual Meeting, wishes to commend the Division K-8 "Committee on Theory and Fundamental Research" for the excellence of the program, the core of which is presented in this volume of the meeting papers. The Executive Committee of the Division extends their sincere appreciation and congratulations to the Committee's Chairman, J. A. Clark of the University of Michigan, whose vision and persistence made the Symposium possible and successful.

Harold A. Johnson
1960 Chairman,
Heat Transfer Division

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INTRODUCTION

DURING the 1960 Winter Annual Meeting, the Heat Transfer Division of the American Society of Mechanical Engineers, through its Standing Committee K-8 on Theory and Fundamental Research, sponsored a Symposium dealing with the status of Theory and Fundamental Research in Heat Transfer. The 11 papers published in this volume represent a permanent record of the lectures presented at that Symposium. Each of the authors was invited by the Society to prepare a lecture dealing with one phase of the subject. The purpose of each of these lectures was to examine the current status of theory and fundamental research and to discuss new areas where profitable research effort might be directed or where existing areas are in need of deeper study. At the close of the Symposium a panel discussion including all lecturers was moderated by Prof. E. R. G. Eckert. This discussion allowed for an exchange of views between the panelists and the audience.

We wish to express our appreciation to the National Science Foundation with whose co-operation we were able to invite several lecturers from Europe and Australia, thus significantly broadening the Symposium. These arrangements were handled by the University of Colorado under the direction of Prof. Frank Kreith with the assistance of Prof. Kenneth G. Picha of the Georgia Institute of Technology. The planning of the Symposium was done by several sub-committees under the direction of Prof. Joseph Kestin of Brown University, Prof. Harold Sogin of Tulane University, Prof. Benjamin Gebhart of Cornell University and Mr. Stanley J. Green of the Westinghouse Atomic Power Division.

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Thermal Radiation Characteristics of Surfaces

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In dealing with engineering problems, one perforce is concerned with engineering systems, and hence one must consider radiation interchange at actual surfaces of operating equipment. This necessitates the determination and inclusion of the effects of surface roughness, oxide layers or other chemical films, dirt and grease, paints, and other types of surface coatings such as flame-sprayed and evaporated coatings. The spatial distribution and wavelength distribution of the incident and emitted radiation must also be considered. In other words, the engineer deals with the characteristics of a system rather than the properties of a pure substance. The reflectivity (or emissivity) of a polished surface of a pure homogeneous substance can be predicted in terms of other measurable properties; whereas, in general, it is impossible to predict the reflectance (or emittance) of any but very simple systems. For this reason it is recommended that when radiation exchange is a critical factor in an engineering problem, measurements of the radiant characteristics of the proposed materials should be made, and the effect of the proposed operating conditions on these characteristics be ascertained if possible.

Thermal radiation problems encountered in engineering usually involve several surfaces (sources and sinks) of different temperatures and thermal radiation characteristics. Each surface is irradiated by radiation coming from all the surfaces seen by it; the wavelength distribution of this incident radiation is dependent upon the spectral radiosity of the source and the nature of the intervening media traversed by the radiation. Part of the radiation incident on the surface will be reflected, and the spectral and spatial distribution of the reflected energy may be desired. Part of the energy will penetrate into the material and be absorbed; the rate at which energy is absorbed as a function of depth is also wanted. Finally, part of the radiation may be transmitted completely through the material, part of this radiation escaping from the surface and part being reflected back into the material again. It should be possible to specify the spectral and spatial distribution of the transmitted radiation.

The radiant characteristics of most engineering materials vary with the angle θ measured from the normal to the surface, the azimuth angle φ measured relative to some given surface direction (e.g. direction of rolling), the wavelength or frequency of the radiation, the polarization of the radiation, and the temperature and nature of the material. This means that many different radiant characteristics and their relationships must be defined. This paper reviews some of the definitions and relationships.

The equations for the reflectivity of smooth isotropic surfaces as obtained from electromagnetic theory are next presented and briefly discussed for both dielectrics and metals. Reflectance of typical systems is next discussed, including thin films, surface coatings and rough surfaces. Measurement problems and some types of measurement equipment are reviewed. Finally, some of the areas and problems requiring further development are described.

INTENSITY OF RADIATION

In discussing thermal radiation one of the most important fundamental quantities is the spectral or monochromatic intensity. The spectral intensity