PROGRAMME

Commemorative Paper

AA1. Contributions of H. Schardin to the Theory and Application of the Shock Tube. H. REICHENBACH, *Ernst Mach Institut.* —The meeting of the 6th International Shock Tube Symposium—held for the 1st time outside the U.S.A.—in Freiburg can be attributed to the invitation from H. Schardin. Unfortunately he cannot take part in this symposium personally. He was particularly interested in this event and had made the early preparations for it. In memory of H. Schardin, some of his contributions to the theory and use of the shock tube for the solution of unsteady flow problems will be recalled. Parts of a motion picture film he prepared shortly before he died will be shown. He presented this film before the 7th International Congress on High-Speed-Photography in Zurich in 1965.

Session A. Shock Structure and Reactions

(R. J. EMRICH presiding)

A1. Shock Tubes in Rarefied Gas Flow Research. D. COLES, H. W. LIEPMANN, A. ROSHKO, and B. STURTEVANT, *California Institute of Technology.* —The flow within a shock wave is governed by the relaxation times of the molecular degrees of freedom. Advances in shock tube design and instrumentation have made it possible in recent years to resolve all the relaxation times including the shortest, corresponding to the translational degree of freedom. The shock tube thus becomes an important tool for critical experiments in the study of the range of applicability of the Navier–Stokes equations and similar approximations and of the character of solutions of the Boltzmann equation. Significant progress has been made recently in the understanding of the most obvious such problem, the flow within a shock in a monatomic gas. Theory and experiment are now in substantial agreement and the over-all process of energy exchange is understood. Problems connected with shock wave reflection from real walls have made progress but a host of problems remain to be studied including surface interaction effects. The extension of this type of shock tube research to more complicated systems, reacting gases, gas mixtures, and the like has begun and some progress can be reported. Recent experimental progress is illustrated by a number of measurements made at GALCIT in the 17- and 6-in. shock tubes. Sophistications in shock tube design and instrumentation will be discussed.

A2. Structure of Strong Shock Waves. D. L. TURCOTTE and I. M. SCHOLNICK, *Cornell University.* —A model is proposed for the structure of strong waves which explicitly accounts for the existence of a near molecular beam, hypersonic flow upstream and of a subsonic, hot continuum flow downstream. This is accomplished by considering the conversion of the beam into the continuum through collisions. Appropriate continuum equations are derived including the input of mass, momentum, and energy from the beam particles. The particles in the molecular beam are assumed to be converted into members of the continuum in a single collision; and the collision transport phenomena associated with the continuum are assumed to be governed by the Chapman–Enskog expressions. Comparisons with other models for shock structure and with experimental results are given. In view of its simplicity the present model should be applicable to other hypersonic, rarefied flow problems.

A3. Measurement of Shock Structure in Binary Gas Mixtures. A. BEYLICH, *Institut für Mechanik, T.H. Aachen.* —The influence of barodiffusion on the broadening of shock waves was 1st investigated by Cowling (1942). His and later Sherman's work (1960) give a characteristic overshoot for the heavy species, if $f_0 \theta$ is of order unity (f_0 is mass fraction of the heavy molecules, $\theta = M_1/M_2$). These results are not in agreement with those based on Mott-Smith's approach (Fujimoto 1964, Oberai 1965, 1966). In this paper the gas luminescence by the electron beam method is used in a shock tube for measuring density profiles in N_2-H_2 mixtures. In particular the profile of N_2 is measured for different concentrations. No overshoot could be seen down to 5% N_2. The application of the electron beam method required special evaluation associated with shock tube measurements of nonstationary flow.

A4. Steady Expansion of Shock-Heated Gases for Recombination Studies. M. W. SLACK, K. N. C. BRAY, R. A. EAST, and N. H. PRATT, *University of Southampton.* —A detailed investigation of the gas dynamic features of Wilson's shock tube technique for measuring recombination rates of shock heated gases is described. Wilson's recombination measurements in oxygen/argon mixtures indicated that such a study was necessary before application of the technique to other gases of interest in reentry and propulsion. A combined experimental and theoretical study has therefore been undertaken of the flow downstream of a double Prandtl–Meyer expansion in shock heated gases. Various diagnostic techniques have been used to examine the state of the gas in a constant area channel in which the gas relaxes after the sudden cooling process imposed by the steady expansion. Measurements of static pressure and of the unsteady wave system (using stagnation point heat transfer and infra-red emission techniques) have been obtained and compared with theoretical predictions. The results showed good agreement between experiment and theory but indicated that the required flow is only generated over a limited range of flow Mach number. Investigation of the upper and lower limits has thrown light on the flow breakdown processes and has defined the regime in which the technique may be used for studies in which N_2, Ar, and Ar/CO_2 mixtures are used as diluents. The present results together with those of Wilson are discussed in relation to other methods of obtaining expansion flows for relaxation studies. Mention is made of current work on iodine recombination and the hydrogen–oxygen system using this technique.

A5. A Shock Tube Study of the Effects of Nitrogen and Water Vapor on Recombination in the Hydrogen–Oxygen System.* R. W. GETZINGER and L. S. BLAIR, *Los Alamos Scientific Laboratory.* —Thermonuclear recombination in reacting hydrogen–oxygen mixtures has been investigated in a shock tube at 1250°–1779°K in the presence of significant amounts of nitrogen and water vapor. An OH ultraviolet line absorption technique was used to follow the progress of the over-all reaction. Selective variation of the initial composition, which for the water vapor experiments required the development of a special flow-fill apparatus to