

ABSTRACT

The problem of calculating shock temperature indirectly from experimental data without assuming thermodynamic properties is formulated and solved theoretically. In principle, the (e-p-v) and (T-p-v) equations of state can be constructed in an overlapping domain of the (p-v) plane from a family of Hugoniot curves centered at points of known energy and temperature.

Experiments were performed in an attempt to construct these equations of state for silicone fluid 210. Shock and free surface velocities were measured to determine Hugoniot curves in the 300-kbar regime, and energies and densities were measured from -30° to $+260^{\circ}\text{C}$ along the atmospheric isobar to determine the initial states of the shock wave experiments. In practice, it was necessary to assume a form for the (e-p-v) equation of state, since the differences in volumes between states on Hugoniot curves at the same pressure above 40 kbar were found to be comparable with the experimental error in measuring the volumes of each of these states. The data were fitted to a Mie-Grüneisen type (e-p-v) equation of state with variable C_v and $(\partial p/\partial T)_v$, since Hugoniot points indicated a linear dependence of energy on pressure along an isochore, and C_v varied along the atmospheric isobar. Shock temperatures on the 25°C Hugoniot were calculated at points of intersection with isentropes and by integrating with constant atmospheric pressure values of C_v . The position of the 296°C isentrope limits the temperature calculation with isentropes to values below 522°C and 58 kbar, and the values around 50 kbar are 8% lower than those calculated with the 25°C value of C_v , since C_v increases along the Hugoniot curve. Temperature calculations above 58 kbar assumed the 296°C value of C_v . Considerably more experimental work would be required over the entire pressure range to permit determining equations of state of silicone 210 without making assumptions.

I. INTRODUCTION

The use of shock waves to study the high pressure environment in the kilobar regime is based on the assumption that thermodynamic equilibrium is established behind the shock, where material behaves as a perfect fluid. The method is limited at the present time, however, since the mechanical state variables can be measured in shock wave experiments but the thermal state variables cannot. Thus shock wave data are insufficient to determine an equation of state, and shock wave studies provide an incomplete characterization of the high pressure environment. In addition, shocked states are incomplete thermodynamic systems unless shock temperature can be determined, and their characterization is an equation of state problem equivalent to that of determining the temperature-pressure-specific volume (T-p-v) equation of state. In practice, this problem has been solved by assuming thermodynamic properties that allow the unknown state variables to be calculated. More specifically, the form of a complete equation of state is assumed and shock wave data are used as boundary conditions to determine arbitrary functions that would otherwise be undefined. In some cases¹ the form of the complete equation of state is an explicit assumption, in others²⁻⁴ it is implicit in the assumptions that enable the state variables to be calculated. But the significance of such a characterization depends upon the correspondence between the assumed and the actual thermodynamic properties of the material.

The present paper describes an attempt to determine shock temperature indirectly from experimental data so as to provide a complete characterization of shocked states without assuming thermodynamic properties. The problem of calculating shock temperature is formulated and solved theoretically. The equations governing shocked states and the identities of thermodynamics⁵ are combined to define the experimental data required to construct equations of state without assuming their form. Dow Corning silicone 210 fluid was used as a test liquid.