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EQUATION OF STATE FOR ALUMINUM, COPPER, AND LEAD IN THE HIG PRESSURE REGION

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An equation of state for metals is considered, which differs from the Mie-Grüneisen equation of state for a solid body in taking into account the electronic components of the energy and pressure. New data from the dynamic compression of metals are presented, on the basis of which equations of state are derived for aluminum, copper, and lead in the high pressure region.

INTRODUCTION

THE behavior of metals under pressures of several million atmospheres and temperatures of some tens of thousands of degrees may be described by an equation of state, if their compressibility curves at the absolute zero of temperature, the specific heats of the lattice and the electron gas, and their Grüneisen coefficients (defined as the ratio of the thermal pressure to the thermal energy density) are known. Such equations of state cannot be obtained theoretically, since quantum-statistical calculations of the compressibility by the Thomas-Fermi and Thomas-Fermi-Dirac methods lead to an increased pressure which does not reduce to zero at normal density. Solid state theory also does not allow the calculation of Grüneisen coefficients for the lattice, establishing merely the connection between these coefficients and the extrapolated "cold" compression curve.[1-3] For the non-transition metals, our knowledge of the thermal components of energy and pressure caused by the excitation of the electron gas is quite complete and reliable. The validity of the theoretical results in this field are confirmed by measurements of the electronic specific heat at temperatures close to absolute zero. At the present time, of course, we can deal only with semi-empirical equations of state, based on direct experimental measurements of the compressibility.

As a source of information about the pressure region of interest to us, the authors have made use of data from individual single dynamic compressions. The transition from a dynamic adiabatic to the general equation of state connecting the pressure with the density and temperature is possible if additional data is available, for example on the shock compressibility of porous bodies,[4] or with the aid of the theoretical relationships, mentioned above, between the Grüneisen coefficients and the curve of cold compression. This second method has been put into practice in a work by Walsh and his collaborators,[5] devoted to the state equations for metals up to pressures of 5×10^5 atm.

The main difference between our work and the above consists in the considerably wider range of pressures and temperatures covered, and in taking into account the electronic components of energy and pressure, which cannot in any case be neglected for temperatures of $1-2$ ev. In this paper we also present data on the dynamic compression of aluminum up to pressures of 2×10^6 atm and the results of new measurements of the compressibility of copper, lead, and iron at pressures of 10^6, 2×10^6, and 4×10^6 atm.

1. DYNAMIC ADIABATS OF ALUMINUM, COPPER, LEAD, AND IRON

The dynamic adiabats of copper and lead up to 5×10^5 atm have been described by Walsh[5] and in reference 6. In the present paper we also present the results of dynamic compression measurements on these metals up to pressures of 3.5×10^6 atm. For aluminum the observed range of pressures has amounted to 5×10^5 atm.[5,7,8] In this section we present the results of the compression of aluminum by strong shock waves up to 2×10^6 atm, obtained in the authors' laboratory, and new results on copper, lead, and iron in the pressure range from 10^6 to 4×10^6 atm. To improve the precision, it was necessary to make new measurements for the following reason. The dynamic adiabat for iron, used in reference 6 as a reference standard for determining the compressibilities of other elements at 1.3