1. INTRODUCTION

This is a review of the physical principles and experimental data on which methods of calculating compressible turbulent flows must be based. It deals mainly with supersonic and hypersonic boundary layers, but the limited available information on other variable-density flows at high and low speeds will be discussed, for its own sake and for the light it throws on boundary-layer problems. Combustion has recently been reviewed by Libby and Williams (1976) and is therefore omitted from this paper, as are aerodynamic noise and some specialized aspects of high-speed flows which cannot be authoritatively reviewed in the open literature. In general, phenomena which could occur in laminar flow, such as shock-wave/boundary-layer interaction, are discussed only with reference to turbulence behavior: also, we treat only turbulence models and not the details of complete calculation methods. A general familiarity with low-speed turbulent flows is assumed.

The obvious question to ask about compressible turbulent shear layers is "How do they differ from incompressible turbulent shear layers?" Nearly all research work has been aimed at answering this question, nearly all calculation methods are extensions of low-speed methods and would function at low Mach number as a special case. It is now generally accepted that the direct effects of density fluctuations on turbulence are small if the root-mean-square density fluctuation is small compared to the absolute density: this is Morkovin's hypothesis (Favre 1964, p. 367). This means that the turbulence structure of boundary layers and wakes at free-stream Mach numbers M_e less than about 5, and of jets at Mach numbers less than about 1.5, is closely the same as in the corresponding constant-density flow. By "turbulence structure" we mean dimensionless properties like correlation coefficients and spectrum shapes: ratios of turbulence quantities to mean flow quantities, such as the skin-friction coefficient $c_f \equiv \tau_w / \frac{1}{2} \rho_e U_e^2$ are greatly affected by the influence of mean density changes on the mean motion. The effect of mean density variations in x or y on the turbulence structure is <u>not</u> covered by Morkovin's hypothesis but is often negligible at the lower Mach numbers if streamwise pressure gradients are small. Therefore assumptions about turbulence structure that give good results in calculation methods for constant-density flow will, if properly