1. INTRODUCTION

The objective to achieve in computational fluid dynamics is to calculate an entire flow field either around an arbitrary obstacle or through a channel of any shape. The flow should be unsteady, three dimensional, compressible and turbulent. At hypersonic speeds, regions of reacting flow (dissociation, ionization, etc.) might also be considered. The equations to describe this enormous task are the Navier-Stokes equation, the energy equation, the global and partial continuity equations and other closure model equations describing turbulence and reacting gas effects. It can easily be shown that, at present, no computer could provide either the capacity or the necessary calculation speed to fulfil this task.

Thereby, coming back to the reality of today, the governing equations have to be simplified such that the properties of the remaining set of equations still describe the flow to be considered. For instance, when the viscous terms in the Navier-Stokes equations are neglected, one arrives at the Euler equations. They can be used to determine far field flows where the interaction with the viscous layer is not dominant. However, a separation bubble on a surface of a wing cannot be detected without providing viscous flow calculations near the body surface; separation is a matter of viscous effects.

As indicated already, different types of flows can be treated by examining their physical characteristics in detail and in this way establishing the appropriate governing equations by the correct reduction of the general set of fluid mechanical equations. This is what Prandtl (Ref. 1) did in 1904 concerning a thin layer near walls where the influence of viscosity normal to the body surface is dominant. He called this layer a "boundary layer". The important detail of the physical meaning of this kind of flow is that the main flow velocity tends to zero approaching the wall. The gradient of this velocity component in the direction normal to the surface is large compared to the gradient of this component in the downstream direction.

This observation leads to an important change in the character of the governing equations from the elliptic to the parabolic type which makes a numerical downstream marching procedure applicable. Reversed flow therefore cannot be calculated with a simple boundary layer method, but the flow field very near to the separation point, where the reversed flow starts, can be very well detected.

The boundary layer theory will be the subject of this paper. Prandtl's idea will be described in detail as an introduction. The hierarchy of the boundary layer equations will be discussed; that is, the relationship of the different types of boundary layer equations to the Navier-Stokes equations will be demonstrated. Furthermore, it will be pointed out that there are transformation techniques to reduce the problems of solution. A generalized discretization scheme will be applied to a set of laminar compressible boundary layer equations and a numerical solution scheme for calculating the remaining tri-diagonal linear difference equations will be shown. A sample calculation of a laminar boundary layer along the symmetry line of a highly inclined ellipsoid be will the conclusion.

This paper deals only with the laminar boundary layer theory. The description of turbulence needs additional effort, especially in seeking suitable turbulence models for ones purposes, but it does not affect the principal solution procedure. As this paper is meant to give an introduction to the boundary layer theory and its methods of solution, turbulent boundary layers will not be considered, but an overview on recent turbulence models is given in references 2, 3, 4 and 5.