REPORT 1135

EQUATIONS, TABLES, AND CHARTS FOR COMPRESSIBLE FLOW [1]

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SUMMARY

This report, which is a revision and extension of NACA TN 1428, presents a compilation of equations, tables, and charts useful in the analysis of high-speed flow of a compressible fluid. The equations provide relations for continuous one-dimensional flow, normal and oblique shock waves, and Prandtl-Meyer expansions for both perfect and imperfect gases. The tables present useful dimensionless ratios for continuous one-dimensional flow and for normal shock waves as functions of Mach number for air considered as a perfect gas. One series of charts presents the characteristics of the flow of air (considered a perfect gas) for oblique shock waves and for cones in a supersonic air stream. A second series shows the effects of caloric imperfections on continuous one-dimensional flow and on the flow through normal and oblique shock waves.

INTRODUCTION

The practical analysis of compressible flow involves frequent application of a few basic results. A convenient compilation of equations, tables, and charts embodying these results is therefore of great assistance in both research and design. The present report makes one of the first such compilations (ref. 1) more readily available in a revised and extended form. The revisions include a complete rewriting of the lists of equations, as well as the correction of certain typographical errors which appeared in the earlier work. The extensions are primarily in the directions dictated by increasing flight speeds, that is, to higher Mach numbers and to higher temperatures with the accompanying gaseous imperfections.

Compilations similar to those of reference 1 have been given in other publications, as, for example, references 2 through 6. These references have been utilized in extending the tables and charts to higher values of the Mach number. The extension to imperfect gases is based on the relations presented in references 7 and 8.

SYMBOLS AND NOTATION

PRIMARY SYMBOLS

a	speed of sound
A	cross-sectional area of stream tube or channel
C_N	normal-force coefficient for cones, $\frac{\text{normal force}}{q_\infty S_b}$
c_p	specific heat at constant pressure
c_v	specific heat at constant volume
h	enthalpy per unit mass, $u+pv$
l	characteristic reference length
M	Mach number, $\frac{V}{a}$
p	pressure [2]
q	dynamic pressure, $\rho V^2/2$
q	heat added per unit mass
R	gas constant
R	Reynolds number, $\frac{\rho V l}{\mu}$
S_b	base area of cone
s	entropy per unit mass
T	absolute temperature [2]
u	internal energy per unit mass
v	specific volume, $\frac{1}{\rho}$
u,v	velocity components parallel and perpendicular respectively, to free-stream flow direction
$\tilde{u},\tilde{v}$	velocity components normal and tangential, respectively, to oblique shock wave
V	speed of flow
V_m	maximum speed obtainable by expanding to zero absolute temperature
w	external work performed per unit mass
α	angle of attack
β	$\sqrt{\lvert M^2-1\rvert}$
γ	ratio of specific heats, $\frac{c_p}{c_v}$
δ	angle of flow deflection across an oblique shock wave
θ	shock-wave angle measured from upstream flow direction
Θ	molecular vibrational-energy constant
μ	Mach angle, $\sin^{-1}\frac{1}{M}$
μ	absolute viscosity
ν	Prandtl-Meyer angle (angle through which a supersonic stream is turned to expand from $M=1$ to $M>1$)

[1] Supersedes NACA TN 1428, "Notes and Tables for Use in the Analysis of Supersonic Flow" by the Staff of the Ames 1- by 3-foot Supersonic Wind-Tunnel Section, 1947.

[2] When used without subscripts, p, ρ, and T denote static pressure, static density, and static temperature, respectively.