Conclusion

A method for the determination of the boundary conditions of an elastic bar was described. The measured values may be performed at points which are not necessarily the supports of the bar. The bending stiffness of the bar is not necessarily known.

References

[1] Baruch, M., "Undestructive Determination of the Buckling Load of an Elastic Bar," *AIAA Journal*, Vol. 8, No. 12, Dec. 1970, pp. 2274–2276; also Rept. GITAER 70-1, March 1970, School of Aerospace Engineering, Georgia Inst. of Technology, Atlanta, Ga.

[2] Horton, W. H., Craig, J. I., and Struble, D. E., "A Simple Practical Method for the Experimental Determination of the End Fixity of a Column," *Proceedings of the 8th International Symposium on Space Technology and Science*, Aug. 1969, Tokyo, Japan.

[3] Horton, W. H. and Ford, J. S., II, "Some Experimental Studies on the Relationship Between End Fixity and Critical Load Level for Struts," TR 70-21, July 1970, U. S. Army Aviation Material Labs., Fort Eustis, Va.

[4] Struble, D. E., "Boundary Effects in Structural Stability: A New Approach," Ph.D. thesis, in preparation, Georgia Institute of Technology, Atlanta, Ga.

[5] Iwamoto, Tokaya, "The Effect of End Fixity on the Stability of Structures," Ph.D. Thesis, in preparation, Georgia Inst. of Technology, Atlanta, Ga.

[6] Simitses, G. J., private communication, March 1970, Georgia Inst. of Technology, Atlanta, Ga.

Absolute Velocity Determination in a Hypersonic Low-Density Flow

K. A. BÜTEFISCH*

Deutsche Forschungs- und Versuchsanstalt fur Luft- und Raumfahrt, Aerodynamische Versuchsanstalt Göttingen, Germany

An accurate knowledge of the absolute velocity in a hypersonic low-density tunnel would provide a useful check on the usual methods of stagnation temperature determination above 1400°K, which is based on a comparison of the actual mass flux and heater power with room temperature values. Furthermore, using diatomic nitrogen as a test gas, a definite knowledge of the flow velocity gives some information about the extent of vibrational relaxation. Initial attempts to measure the flow velocity utilize mass flux probes, but the necessity of applying pitot pressure corrections introduces uncertainties.[1]

The described technique for velocity determination is based on time-of-flight measurements of nitrogen ions produced by a short pulsed high energy electron beam.

The following investigations have been carried out in the hypersonic low-density wind tunnel of the AVA Göttingen (West Germany). The stagnation temperature was varied between 600 and 2250°K at a stagnation pressure of 50 atm absolute. The Mach number in the test region was about 20. At stagnation temperatures below 1200°K condensation of nitrogen during the expansion was expected without greatly affecting the velocity measurements.

The stagnation temperature was determined by comparison of the total mass flux of the test gas under experimental and room temperature conditions with the use of carefully measured calibration curves.

To monitor the temperature measurements, the heater power input was observed. A decrease in mass flux at constant power input indicated a change in nozzle geometry and thus rendered the starting conditions of a run invalid.

Received February 22, 1971; revision received April 5, 1971.

* Staff Member.

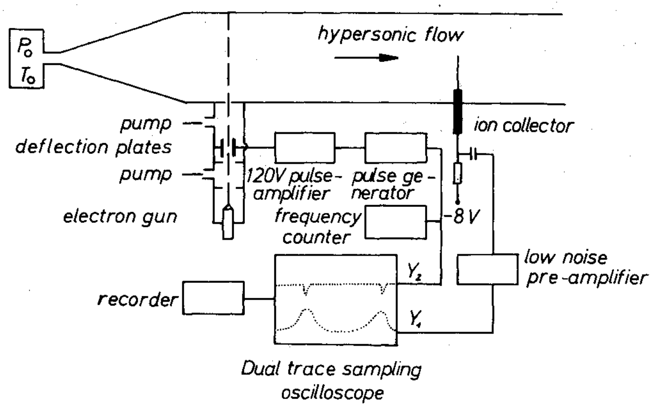

Fig. 1 Schematic drawing of the experimental setup.

The experimental setup is shown in Fig. 1. A 2-μsec pulse of the electron beam (20 KeV, 200 μA) produced ions within a small volume defined by the beam diameter and the beam length across the test region. With the basic assumption of negligible transfer of momentum from the fast electrons to the relative slow molecules, changes of the flow bulk velocity because of the electron beam interaction do not occur. At a distance of 375-mm downstream of the electron beam, the ions were gathered by the ion collector, which consists of a simple isolated tungsten wire of 0.1-mm diameter and 30-mm length suspended parallel to the electron beam. The starting pulse of the electron beam and the amplified ion signal were recorded by a dual trace sampling oscilloscope. The time-of-flight was determinated by varying the repetition frequency of the starting pulse in such a manner, that the $(n + 1)$th starting pulse coincided with the peak value of the nth ion signal. The maximum of the ion signal was used as the mean time of arrival of the ions. The repetition frequency was measured by a quartz stabilized frequency meter. The result could be reproduced within an error of about 0.2%. Using the scanning outputs of the oscilloscope the starting pulse and the ion signal could be recorded.

Since the flight path is known (within an error of $\pm 0.3\%$) the flow velocity was found as the product of measured fre

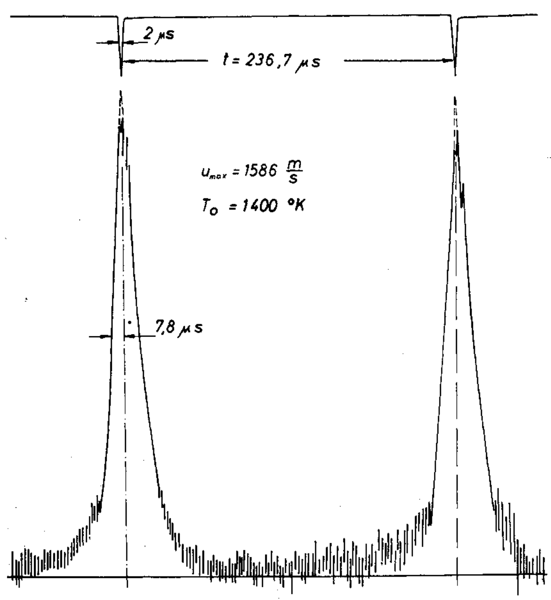

Fig. 2 Starting pulse (upper trace) and ion signal (lower trace).

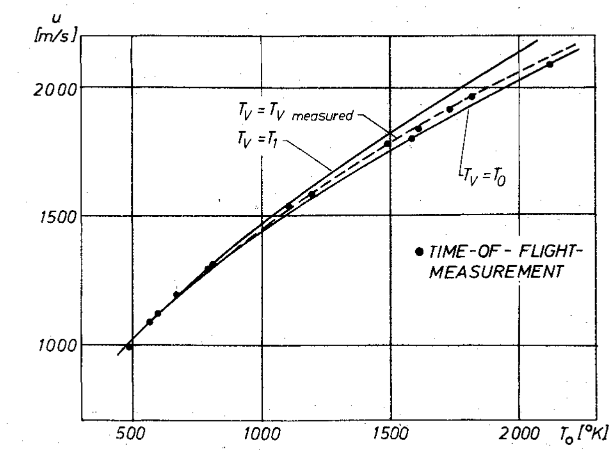

Fig. 3 Flow velocity vs stagnation temperature: comparison—time-of-flight measurement and calculation.

quency times path length. The relative experimental error was estimated to be less than 1%.

Figure 2 shows a typical oscilloscope trace. The upper curve represents two starting pulses having a half-maximum width of 2 μsec. The lower curve shows on the right side the ion signal corresponding to the first upper starting pulse. The measured repetition frequency was equivalent to a time-of-flight of 236.7 μsec. From this, a flow velocity of 1586 m/sec was deduced. A comparison of the experimental flow velocity with data predicted from measurements of stagnation temperature and pitot pressure, has to take into account the vibrational state of the gas. Therefore the vibrational temperature was measured in the same run by the standard electron beam technique.[2,3]

Results and Discussion

Figure 3 shows the results of the time-of-flight velocity measurements. The circles mark the flow velocity data plotted vs the measured stagnation temperature.

The solid curves represent the velocity computed from stagnation temperature and pitot pressure for the case of equilibrium (upper curve) or totally frozen (lower curve) vibrational states.

Most of the experimental data neither lie on the upper nor on the lower curve, but on the dashed curve which represents the flow velocity predicted for the measured vibrational temperature.

It should be noted that the measured vibrational temperature was only about 10% smaller than the stagnation temperature. Although vibrational effects influence the flow velocity only by a small amount, the accuracy of the described method is good enough to indicate even the minute changes in velocity. The good agreement of theory and experiments implies, that the assumptions made for the time-of-flight measurement are valid, namely that the ion velocity is equal to the bulk velocity of the surrounding molecules and that the maximum of the ion signal represents the mean time of arrival of the ions.

References

[1] Koppenwallner, G., Bütefisch, K. A., and Kienappel, K., Forschungsbericht 67-69, 1967, Deutsche Luft- und Raumfahrt, München, Germany; also "Experimentelle Untersuchungen über die hypersonische Düsenströmung bei sehr geringer Gasdichte mit Schwingungs-relaxation," AVA FB 67-40, Sept. 1967, Aerodynamische Versuchsanstalt Göttingen, Germany.

[2] Bütefisch, K. A., Forschungsbericht 69-63, 1969, Deutsche Luft–und Raumfahrt, München, Germany; also "Experimentelle Bestimmung von Rotations- und Schwingungs-temperatur und Dichte mit Hilfe der Elektronenstrahltechnik im Strömungsfeld eines hypersonisch angeströmten Kreiszylinders bei Stautemperaturen von 1100–1800 °K," AVA FB 69-28, June 1969, Aerodynamische Versuchsanstalt Göttingen, Germany.

[3] Muntz, E. P., "Measurement of Rotational Temperature, Vibrational Temperature, and Molecular Concentration, in Nonradiating Flows of Low Density Nitrogen," UTIA Rept. 71, 1961, Inst. of Aerophysics, Univ. of Toronto, Canada.

Radiation from a Porous Wall Heated Internally by a Gas

W. W. SHORT*
General Research Corporation, Santa Barbara, Calif.

Nomenclature

C_p = heat capacity of gas
d = pore diameter
G = mass flow per unit wall area
h = heat-transfer coefficient in pores
k = thermal conductivity of wall
K = thermal conductivity of gas
l = thickness of wall
n = number of pores per unit wall area
P = porosity of wall = $n\pi d^2/4$
Q = radiation from wall
t = wall temperature
T = gas temperature
T_o = gas temperature entering pores
x = distance from gas inlet surface
ϵ = emissivity of solid
σ = Stefan-Boltzmann constant 1.35 × 10^{-12} cal/cm²–°K⁴–sec

Dimensionless quantities

$\eta = x/l$
$\theta_T = T/T_o$
$\theta_t = t/T_o$
$\phi = \sigma\epsilon l T_o^3/k(1-P)$
$\gamma = n\pi dhl/C_pG$
$\lambda = n\pi dhl^2/k(1-P)$
$E = Q/C_pGT_o$

Introduction

THIS Note investigates a radiation source consisting of a porous wall through which hot gases are forced. The gases enter through one surface, heat the wall internally, and emerge from the opposite surface, which is also the radiating surface. This type of device has applications as a high-altitude or space flare. The usual pyrotechnic flares, in which the fuel is exposed to ambient pressure, do not radiate efficiently and often will not burn at very low pressures. Rocket engines are radiation sources that operate in a low-pressure environment; however they are inefficient radiators because most of the heat of combustion is converted to the directed kinetic energy of the products of combustion. Passing the products of combustion through the small channels of a porous wall retains

Table 1 Constants for evaluating radiation source

Graphite wall	Products of combustion
$K = 1.2\ 10^{-2}$ cal/cm-sec°K	$G = 10^{-2}$ g/s-cm² (assumed)
$\epsilon = 1$	$K = 3\ 10^{-4}$ cal/cm-s-°K
$l = 3.5$ cm	$C_p = 0.3$ cal/g-°K
$n = 3.1\ 10^3$ cm^{-2}	$T_o = 2500$ °K
$p = 0.48$	$\gamma = 1.4\ 10^4$
$d = 1.4\ 10^{-2}$ cm	$\lambda = 2.4\ 10^4$
	$\phi = 6.2$

Received March 12, 1971.

* Member of Technical Staff.