It is surmised that because of the generally similar character of supersonic blunt-body pressure distributions these results will also be valid for other probe shapes and Mach numbers, provided the area of the hole is a reasonable fraction of the total frontal area, and, further, that it is symmetrically placed as probe II rather than probe I

Reference

[1] Gracey, W , Coletti, D E , and Russell, W R , "Wind tunnel investigation of a number of total-pressure tubes at high angles of attack," NACA TN 2261 (January 1951)

Chemical Scavenger Probes in Nonequilibrium Gasdynamics

D E Rosner,* A Fontijn,† and S C Kurzius†
AeroChem Research Laboratories, Princeton, N J

DIRECT, local measurements of atom, free radical, excited molecule, and/or ion concentrations are required in the experimental study of nonequilibrium flow fields and for calibrating high enthalpy test facilities In attempts to simulate the conditions of hypervelocity flight it is necessary to know whether the test gas composition (e g , population of excited states) is not, in some sense, singular, particularly when an electrical discharge is used to heat the gas Although gas-sampling techniques have been successfully applied to the study of local stable species concentrations both in subsonic and supersonic steady flows,[1–3] rapid heterogeneous and homogeneous ıeactions in the sampling system have precluded their direct use for unstable species We wish to point out here that this difficulty can frequently be eliminated by introducing a "scavenger" gas immediately inside the probe The scavengeı rapidly and quantitatively reacts with the unstable species in the sampled gas to form one or more stable pıoducts, which can then be analyzed downstream by any one of a numbeı of conventional techniques The authors have successfully applied this principle in sampling nonequilibıium supersonic stıeams of active nitıogen for both atoms and excited molecules Details of the experimental technique, and the implications of this work to our understanding of the chemistıy of active nitrogen will be found in a forthcoming paper [4] Here we confine our attention to some of the implications for aeıodynamic testing

The measurement of local excited molecule concentrations is made possible by the existence of scavengers that are selectively attacked by atoms and/or excited molecules Thus, nitıogen sampled from a Mach 3 plasmajet was reacted with nitric oxide, ammonia, oı ethylene, and measurements were made of scavenger gas destruction (NO, NH_3), a gas-phase chemiluminescence titration end point (NO), and product formation (HCN from C_2H_4) An interesting conclusion of this work is that electronically excited nitrogen molecules can be present in concentrations comparable to that of ground-state atoms, and can thereby exceed the importance of atoms as energy carriers in nonequilibrium plasmajets Absolute atom and excited molecule concentrations determined using scavenger-probe techniques can now be used in conjunction with catalytic detector measurements[5 6] made under identical experimental conditions to determine the contribution of individual energetic species to gas/solid energy transport

Scavenger probes lend themselves to use in high-temperature systems since they can be (water) cooled and/or the scavenger gas can be mixed with an inert diluent The technique is generally useful foı quantitative studies of the energetic species of interest in aerodynamic and chemical propulsion applications and may also be used to distinguish between various excited states of the same molecule It is relevant to point out that Fristrom has recently reported on an independent application of the scavenger-probe concept in subsonic, low-pressure flame studies [7 8] Oxygen atom, hydıogen atom, and methyl radical concentrations have been determined using, respectively, NO_2, chlorinated diffusion pump oil vapor, and iodine as the scavenging gases

Although a considerable amount of research has yet to be done, particularly with regard to analyzing mixtures of energetic species in supersonic streams, we feel that scavenger probes are destined to play an important role in the futuıe of nonequilibrium flow diagnostics

References

[1] Tiné, G , *Gas Sampling and Chemical Analysis in Combustion Processes* (Pergamon Press, London, 1961), Sec B

[2] Fristrom, R M , "Experimental determination of local concentrations in flames," *Experimental Methods in Combustion Research-A Manual,* edited by J Surugue (Pergamon Press, London, 1961), Sec 1 4, pp 6–31

[3] Hottel, H C and Williams, G C , "Experimental techniques," *Design and Performance of Gas Turbine Power Plants* (Princeton University Press, Princeton, N J , 1960), Vol XI, Part 2, Sec C, pp 44–91

[4] Fontijn, A , Rosner, D E , and Kurzius, S C , "Chemical scavenger probe studies of atom and excited molecule reactivity in active nitrogen from a supersonic stream " AeroChem TP-47a (December 1963); also Can J Chem (submitted for publication); also presented in part before the Division of Physical Chemistry of the American Chemical Society, 142nd National Meeting, Atlantic City, N J , abstract, p 51T (September 9–14, 1962); cf AeroChem TP 40 ASTIA AD 296 398 (August 1962)

[5] Rosner, D E , "Diffusion and chemical surface catalysis in a low temperature plasmajet–the determination of atom concentrations in nonequilibrium supersonic streams of activated nitrogen," J Heat Transfer **C84**, 386–394 (November 1962)

[6] Rosner D E , "Catalytic probes for the determination of atom concentrations in high speed gas streams," ARS J **32,** 1065–1073 (1962)

[7] Fristrom, R M , "Scavenger probe sampling: a method for studying gaseous free radicals," Science **140,** 297–300 (April 1963)

[8] Fristrom, R M , "Radical concentrations and reactions in a methane oxygen flame," *Ninth Symposium (International) on Combustion* (Academic Press Inc , New York, 1963), pp 560–575

Received July 17, 1963; revision received September 25 1963 Based on research supported by the U S Air Force Office of Scientific Research, Propulsion Division, under Contract AF 49(638)300

* Aeronautical Research Scientist Member AIAA

† Physical Chemist

Temperature Distributions Downstream of a Moving Heat Sink

Ashley F Emery*
University of Washington, Seattle, Wash

Nomenclature

a = half-width of the heat sink, ft
h = heat transfer coefficient, Btu/hr-°F ft^2
k = thermal conductivity of the plate, Btu/hr-°F ft
l = thickness of the plate, ft

Received September 13, 1963; revision received February 10, 1964

* Assistant Professor of Mechanical Engineering