Procedure for Reliable Preparation of Shock Tube Test Gas Mixtures Containing Water Vapor*

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SHOCK tube spectroscopic measurements[1]–[3] of the emission, absorption, and kinetics of H_2O and OH are usually performed with test gas mixtures of water vapor diluted in argon in order to readily achieve high shocked gas temperatures.

Mixtures of argon and water vapor prepared in external mixing systems, however, exhibit excessive preferential adsorption of the water vapor on the walls of the gas handling equipment and the shock tube during the bleed-in procedure. The extent of surface adsorption of the water vapor may be as high as 30–50% of the initial concentration value.[4] In addition to the uncertainties of over-all concentration introduced by the adsorption, concentration gradients may be set up within the shock tube so that samples drawn from the tube just before firing may not be representative of that in the region of observation.

Attempts to overcome these difficulties by conditioning the shock tube walls through diffusion mixing from the vapor pressure above bulbs of liquid water open to the test section gave erratic results. Repeated flushing cycles with a mixture left in the tube for 10 min and then pumped out to about 1–2 mm Hg before bleeding in a fresh mixture also proved unsatisfactory.

A successful procedure was arrived at through use of a continuous flushing operation employing the system shown in Fig. 1. This system used a regulated argon flow, bubbled continuously through a series of bulbs containing degassed water. A flow meter monitored approximate flow rates, regulation being achieved by bellows valves at the inlet and outlet of the flow system. A cold trap prevented the water vapor from contaminating the vacuum pump oil. A small air conditioning unit recirculating air within an insulated enclosure allowed controlled temperatures of 0–25°C to be maintained in the mixing system. Since the ratio of vapor pressure above the liquid water compared to the total mixture pressure determined the water vapor concentra-
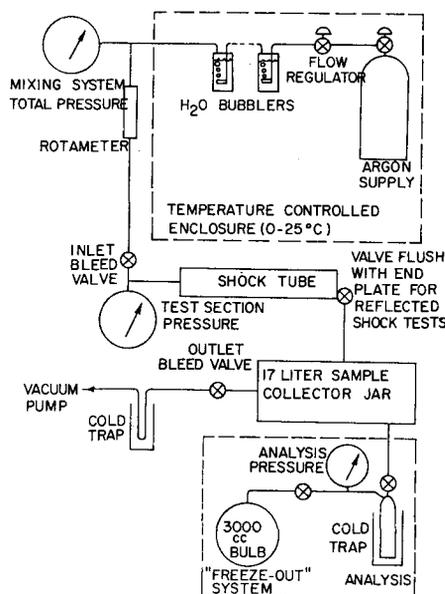

FIG. 1. Schematic representation of flushing system for argon-water vapor mixtures.

tion, the cooling system allowed low percentage concentrations to be obtained without dangerously overpressurizing the associated glassware.

For experiments on OH emission behind reflected shocks, water vapor concentrations as low as 0.5% were obtained using a water-bubbler temperature of 6.7°C and mixture total pressure of 2 atm absolute. Concentrations of about 20% water vapor have been obtained for H_2O absorption studies using a similar flushing system with room temperature water and a mixture total pressure around 5 in. Hg absolute.

Verification that the procedure was indeed furnishing shock tube test gas concentrations as calculated from water vapor pressures and total mixture pressures was made with

a "freeze out" analysis system as shown in Fig. 1. After flushing, mixtures for analysis were drawn from the 17-liter sample collector jar through a cold trap into a glass analysis system of about 3200 cc. Evaporation of the ice in the trap into a calibrated fraction of the analysis volume gave a pressure reading indicative of the water vapor concentration.

With water vapor concentrations near 3%, flushing times of over 30 min at about 1000-cc/min flow rate (at mixture supply conditions) were required to get concentrations in the shock tube of 95% or better of the calculated values. This flushing time and rate corresponds to about 30 to 40 shock tube volume changes. Analyses made at both ends of the shock tube, 10 min or more after the flushing

was completed, showed that adsorption equilibrium was attained since the concentration was uniform and remained constant at the value calculated from the mixing supply conditions.

[1] M. Lapp, J. Quant. Spectr. Radiative Transfer 1, 30 (1961).
[2] C. C. Ferriso, "High Temperature Infrared Emission and Absorption Studies", Scientific Report AE 61–0910, General Dynamics/Astronautics, San Diego, California, September 1961.
[3] S. H. Bauer, G. L. Schott, and R. E. Duff, J. Chem. Phys. 28, 1089 (1958).
[4] From measurements in this laboratory on samples drawn out through the gas inlet lines after 5–10 min in the shock tube. Initial concentrations ~3% H_2O, test gas pressure 50 mm, initial shock tube vacuum 0.1 μ at about 1- to 2-μ/h leak rate.