

pulse of about 0.5- $\mu$ sec rise time and 5- $\mu$ sec duration. The 2D21 remains conducting and serves as a lock-out, which allows transmission of only one output pulse to eliminate multiple triggering of subsequent stages. A normally closed switch and indicator lamp are provided for resetting.

The trigger pulse proceeds to a waveform generator and on to variable delay<sup>2</sup> pulse generators. A variable firing delay is adjusted to position the image on the film, i.e., to allow time for the mirror to rotate to the proper photographic position before the event occurs. Thus, the RMC automatically supplies a firing signal when the mirror reaches, simultaneously, a predetermined writing speed and a particular rotational position.

A measurement was made of the accuracy of the rotating mirror frequency-sensing function. The experimental arrangement was similar to that for delay adjustments with the addition of another photomultiplier device and pinhole at a known distance from the first device along the film plane in the direction of mirror rotation. The two photomultiplier outputs were mixed and observed on an oscilloscope as two sharp pulses displaced from each other in time (also indicating the camera writing speed). Variations in time between pulses indicated a frequency-determining accuracy of  $\pm 0.14\%$ . Variation in mirror rotational speed during the time required for the reed contact function is negligible because of the relatively slow rate of change of rotation (a few seconds to full speed), particularly when the system is set to operate near full speed.

Mirror positioning accuracy was observed using a fast light fiducial with relatively negligible jitter. Variations in fiducial position at the film plane indicated a maximum jitter of about 1.5  $\mu$ sec, probably the result of the 3- $\mu$ sec rise of the input squaring and sharpening circuits and the 2D21 conduction.

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<sup>1</sup> F and M Electronics, Albuquerque, New Mexico.

<sup>2</sup> Tektronix type 162 and 163, respectively.

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

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**S**HOCK tube spectroscopic measurements<sup>1-3</sup> of the emission, absorption, and kinetics of H<sub>2</sub>O and OH are usually performed with test gas mixtures of water vapor diluted in argon in order to readily achieve high shocked gas temperatures.

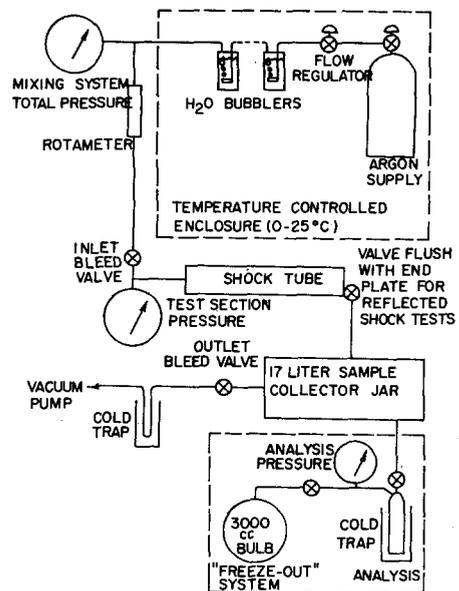


FIG. 1. Schematic representation of flushing system for argon-water vapor mixtures.

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.<sup>4</sup> 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 concentration, the cooling system allowed low percentage concen-

trations 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<sub>2</sub>O 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.

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<sup>1</sup> M. Lapp, *J. Quant. Spectr. Radiative Transfer* **1**, 30 (1961).

<sup>2</sup> C. C. Ferriso, "High Temperature Infrared Emission and Absorption Studies", Scientific Report AE 61-0910, General Dynamics/Astronautics, San Diego, California, September 1961.

<sup>3</sup> S. H. Bauer, G. L. Schott, and R. E. Duff, *J. Chem. Phys.* **28**, 1089 (1958).

<sup>4</sup> 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<sub>2</sub>O, test gas pressure 50 mm, initial shock tube vacuum 0.1 μ at about 1- to 2-μ/h leak rate.

## Construction of a Small Valve for High Vacuum

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THE development of an electron probe x-ray micro-analyzer at the Smithsonian Institution required a small high-vacuum valve to interrupt the air flow through a straight 0.040-in. hole in a heavy wall of type 303 stain-

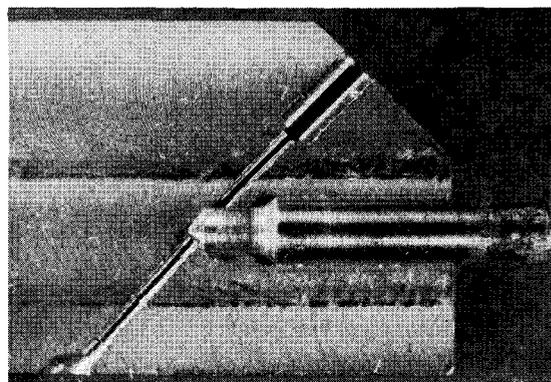


FIG. 1. Test valve, milled to show the central section.

less steel. A  $\frac{1}{8}$ -in. hole for the tip of the valve rod intercepted the hole for the air at an angle of 45° from the high vacuum end of the hole. After several unsuccessful attempts to polish a valve seat at the bottom of the hole for the valve rod, we made a seat by the following quick method.

Before drilling the 0.040-in. hole, we drilled the hole for the valve rod  $\frac{1}{8}$  in. shorter than the final depth. Then we machined the end of a  $\frac{3}{16}$ -in. drill rod to the following shape required for the valve seat. The final  $\frac{1}{8}$ -in. length was a cylinder  $\frac{1}{8}$  in. in diameter terminated by a cone of approximately 60° included angle. We hardened the rod to Rockwell C64 and polished it with 6-μ diamond polishing compound to a mirror finish. We placed the hardened rod in the  $\frac{3}{16}$ -in.-diam drilled hole, and a hydraulic press applied sufficient force to the rod to drive it  $\frac{1}{8}$  in. deeper than the hole had been drilled. After extraction of the rod the bottom of the hole appeared as a polished replica of the end of the hardened rod. Then we drilled the 0.040-in. hole for the air through the center of the valve seat.

Figure 1 shows a test valve, milled to show the central section, with the hardened rod replaced in its final position.

We fused *in vacuo* a drop of pure silver on the end of another, unhardened, drill rod and machined the silver to fit the prepared seat. The valve rod was a running fit in the hole prepared for it. We operated the silver-tipped drill rod, within a stainless-steel expansible bellows, by a lever in order to multiply the force applied to the valve rod.

The leak rate of air through the valve was less than 0.01 μl/sec for a seating force of 140 lb. Higher seating forces resulted in lower leak rates. A higher leak rate, which for our purposes was insignificant, resulted from seating the valve rod originally in one position and then reseating the valve after rotation of the rod to a new position. Although we have attempted no bakeout above 150°C, the materials used in the construction of the valve suggest that much higher baking temperatures would have been safe. The valve has been operated without failure several thousand times during the last four years.