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1 September to 30 November 1965

Bow Shock Calculations

The final report on this phase of the research work has been published.[1] An abstract of the report is included here as an appendix.

A meeting concerning Apollo bow-shock flow fields was held at the Manned Space Flight Center in Houston on November 3. The results described in Ref. 1 were reported at that meeting.

Vibrational Relaxation

Investigations of the vibrational relaxation of a simple harmonic oscillator model of the molecule were reported in Ref. 2 and comparison of these results with very recent[3] numerical calculations were made in the last progress report. These comparisons illustrated that the results of Ref. 2 were accurate up to impact velocities of 8×10^5 cm/sec. During the past quarter this material has been submitted for publication.[4] It has been decided to terminate this phase of the work for the present time in order to concentrate the remaining funds on completion of the experimental phase of the program.

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Vacuum Ultra Violet Radiation

In the last progress report two problems were discussed, together with suggested solutions which were to be studied. The problems are the large stray-light component in the spectrographic system, and the question of optically thick test gas conditions. The former is due to the relatively small amount of light normally available below 1200 Å, compared with the amount that is scattered from longer wavelengths. Although the scattered fraction may be small, when weighted by the high intensities at wavelengths greater than 1500 Å resulting from a thermal source at temperatures around 10,000°K, the total stray light component comprises an undesirably large fraction of the radiation measured in the wavelength region of interest. Although this problem does not rule out the capability for making the measurements, it does limit the attainable precision. Thus it was decided to examine a potentially attractive solution, i.e., the suitability of a radiation detector which does not respond to signals of wavelengths greater than about 1300 Å, and which is thus insensitive to the stray light from the grating.

The second problem is due to a combination of factors. The configuration of the shock tube used for these studies does not permit the use of initial test gas pressures below about 1 Torr. After increasing the temperature to 10,000°K, the consequent concentration of nitrogen or oxygen ions and electrons is too high, resulting in blackbody radiation at the shocked gas temperature. Because it is desirable to make the quantitative spectral measurements in the optically thin-gas region, the partial densities of ions and electrons must be reduced. To achieve this, the use of neon as a suitable diluent gas has been studied and looks very favorable.

The experimental and theoretical studies of both these problems have been pursued during the past quarter. The progress that has been made toward their solution will be discussed, and the present status of the program will be presented in greater detail below.

The Use of Neon as a Diluent in the Optically Thick-Gas Problem

Because they are chemically inert at high temperatures, the noble gases are frequently used as diluents in shock tube experiments. Those of higher molecular weights permit high temperatures to be attained, and hence argon is often chosen for this purpose. For the present experiments, neon was found to be a better choice, primarily because the high energies required for electronic excitation or ionization render it optically inactive over the entire wavelength range of the present experiments. It is also suitable from a gasdynamic standpoint. During the past quarter shock tube runs were made to test the suitability of neon as a diluent for the O_2 and N_2 experiments. Temperatures beyond 12,000°K were attained with no difficulty. The radiation from the neon was monitored with a multichannel infrared spectrometer. Even in the near infrared region, where the radiation would be most intense, very little emission was recorded. Hence, it was concluded that the use of neon was a practicable solution to the blackbody-radiation problem.

The CAL normal shock computer program was used to obtain shock-wave solutions for various neon-oxygen and neon-nitrogen mixtures. Typical results of this calculation are illustrated in Figs. 1 and 2, showing the conditions behind the reflected shock wave for a 99 1/2% neon, 1/2% N_2 mixture. Further calculations were made to determine the dilution ratios, assuming

the cross-section values of Hahne[5] for the ion-recombination radiation, and stipulating that the emissivity of the gas be less than 0.2. The results show that 0.5% N_2 in neon and 1.0% O_2 in neon will permit measurements over a broad range of temperature and density. These mixtures were ordered and have been delivered.

Experimental Apparatus Modifications

Rather extensive tests were conducted to determine the suitability of a special photomultiplier tube to the solution of the stray-light problem. A 1P28 phototube constructed entirely of stainless steel was used to record the spectrum of a discharge lamp using hydrogen, argon and neon gas. The lamp produced several prominent spectral lines of these gases between 700 and 1300 Å. The signals from the steel phototube were directly compared with those from the conventional sodium salicylate-phototube combination detector, and found to be superior, especially at wavelengths below 1100Å. In addition, because the photoelectric efficiency of the steel drops to a very low value beyond 1300 Å, the system was blind to radiation at longer wavelengths. The gain characteristic of the tube is independent of wavelength and hence the detector response is that of the photoelectric efficiency of the steel cathode. Based on the results of these tests, it was decided to use these detectors for the present experiments.

A new detector assembly was thus designed for the vacuum ultraviolet spectrometer, in which three steel photomultiplier tubes are deployed in the focal plane behind a variable slit plate. The radiation passes through the open exit slits into a second chamber housing the detectors (Fig. 3).

Because the cathode and dynode elements of the tubes are exposed, the pressure in this chamber is maintained at 10^{-5} Torr during the test, and the high voltage is shunted off directly after the run, when the pressure in the spectrometer would normally rise.

A new CAL grating has been installed in the spectrometer. Together with the new detecting system, it permits operation at 16 or 8 Å/mm, in the 1st and 2nd orders respectively. With the phototubes deployed as shown in Fig. 3, two wavelengths only 60 Å apart can be studied, although the total span can be set to 1000 Å. This feature is very useful in identifying the spectral features of the radiation from the shock tube.

Present Status

All gases and parts have been procured, and the new detector assembly has been fabricated and assembled. The vacuum connections to the phototubes have been checked and found satisfactory.

The shock tube for use in these studies has also been upgraded in several ways. Additional instrumentation ports have been added to provide a more precise measurement of the incident wave speed. The speed is now measured over six 3-foot intervals with megacycle timing counters, from which the shock wave velocity can be determined to within 0.5%. In addition, the gas-handling and vacuum system has been overhauled. Ionization gauges for vacuum measurements and a Baratron differential pressure gauge have been procured (CAL Capital Asset funding). The Baratron is capable of measuring pressures in the mm range with micron precision. It is used to control and measure the initial test gas pressure in the shock tube, and serves

to eliminate any error in this parameter. The rate of pressure rise of the entire shock tube and gas-handling system has been decreased to about 1μ/hr and is deemed more than adequate for the present experiments.

Assembly and calibration of all components will be completed within the next quarter; the shock tube experiments will then be initiated.

References

1. Joss, William W., Application of the Inverse Technique to the Flow Over a Blunt Body at Angle of Attack, CAL Rept. No. AG-1729-A-6, December 1965.
2. Treanor, C.E., Vibrational Energy Transfer in High-Energy Collision, J. Chem. Phys. 43, 532 (1965).
3. Sharp, T.E. and Rapp, D., Evaluation of Approximations Used in the Calculation of Excitation by Collision, I. Vibrational Excitation of Molecules. J. Chem. Phys. 43, 1233 (1965).
4. Treanor, C.E., Transition Probabilities for the Forced Harmonic Oscillator, To be Published as a Comment, J. Chem. Phys., February, 1966.
5. Hahne, Gerhard E., The Vacuum Ultraviolet Radiation from N^+- and O^+ - Electron Recombination in High-Temperature Air, NASA TN D-2794, June 1965.

APPENDIX

Application of the Inverse Technique to the Flow Over a Blunt Body at Angle of Attack

William W. Joss

Abstract

A method for the numerical solution of the flow behind a nonaxisymmetric bow shock is described. This method has been programmed for an IBM 7044 digital computer for the case of an ideal gas, and the calculation time is approximately ten minutes. For a specified bow shock the program generates the subsonic flow, a portion of the supersonic flow, and the body shape which will support the specified shock. Sample results are shown for three different shock shapes.

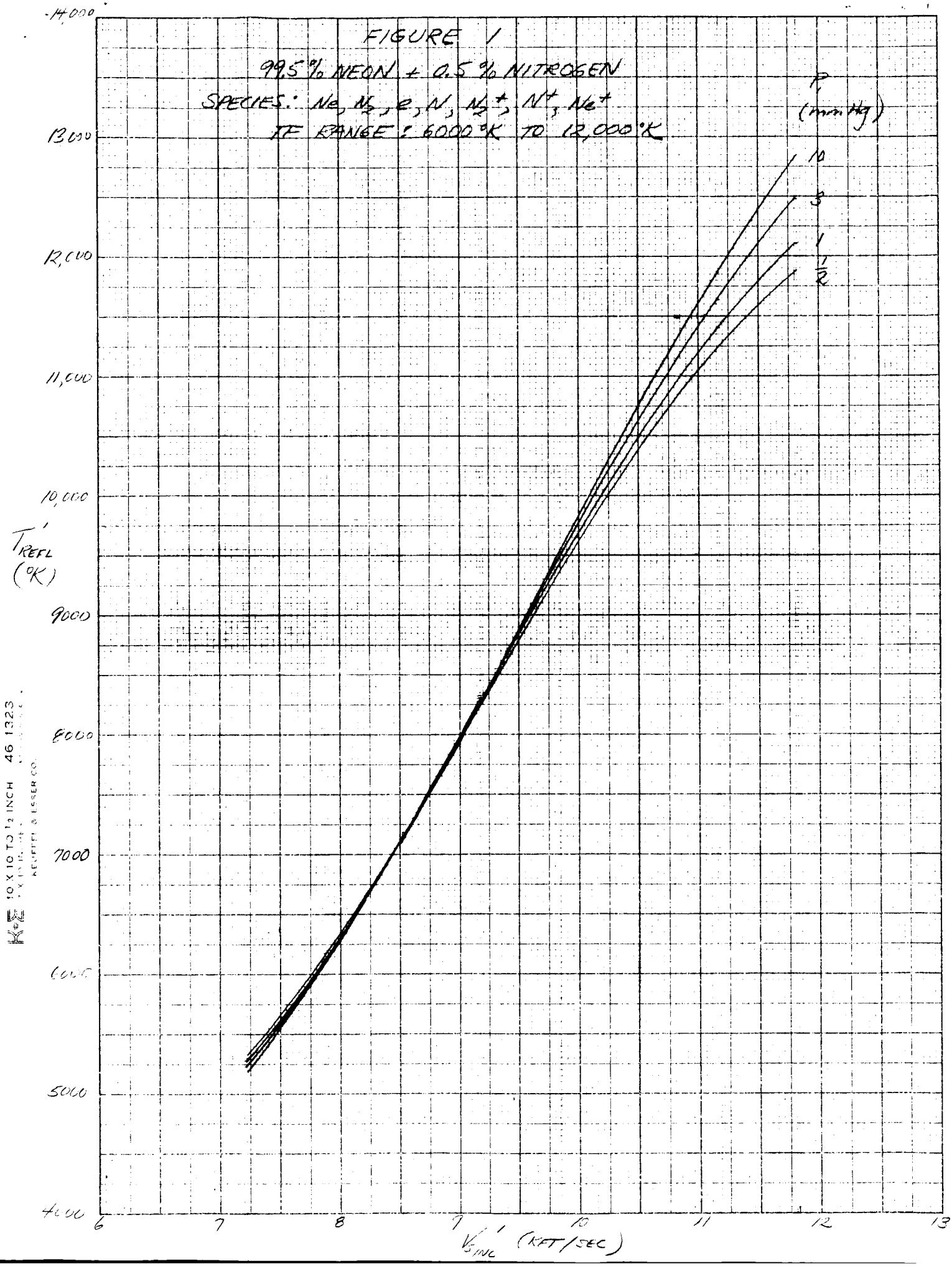
FIGURE 1
99.5% NEON + 0.5% NITROGEN
SPECIES: Ne, N2, e, N, N2+, N+, Ne+
TE RANGE: 6000°K TO 12,000°K
P (mm Hg)
10
5
1
1/2
14,000
13,000
12,000
11,000
10,000
9000
8000
7000
6000
5000
4000
T'REFL (°K)
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V'INC (KFT/SEC)

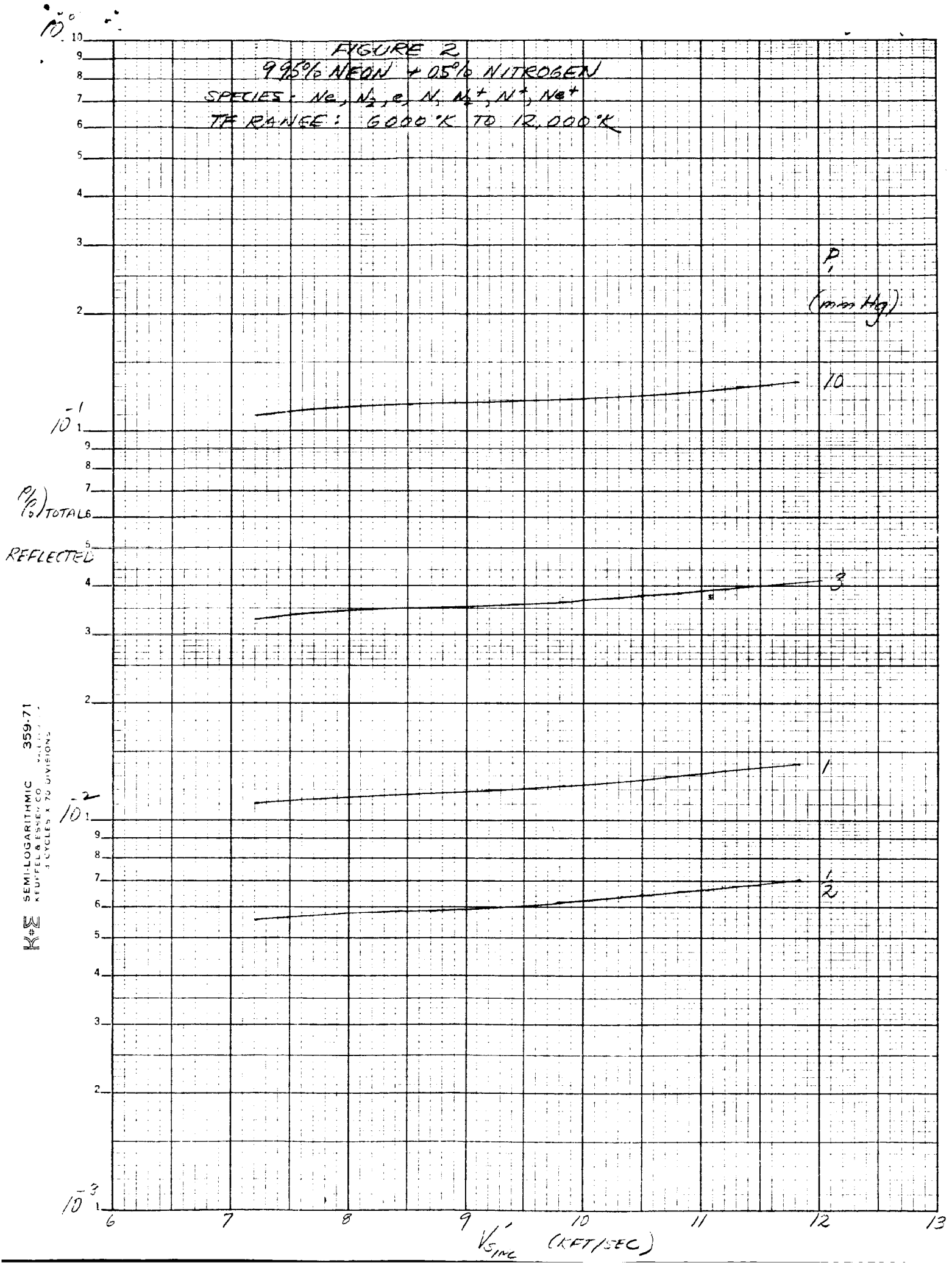
FIGURE 2
99.95% NEON + 0.05% NITROGEN
SPECIES: Ne, N2, e, N, N2+, N+, Ne+
TE RANGE: 6000°K TO 12,000°K
P1 (mm Hg)
10
1
3
2
(P/P0) TOTAL REFLECTED
V'S INC (KFT/SEC)
SEMI-LOGARITHMIC 359-71
KEUFFEL & ESSER CO.
3 CYCLES X 70 DIVISIONS

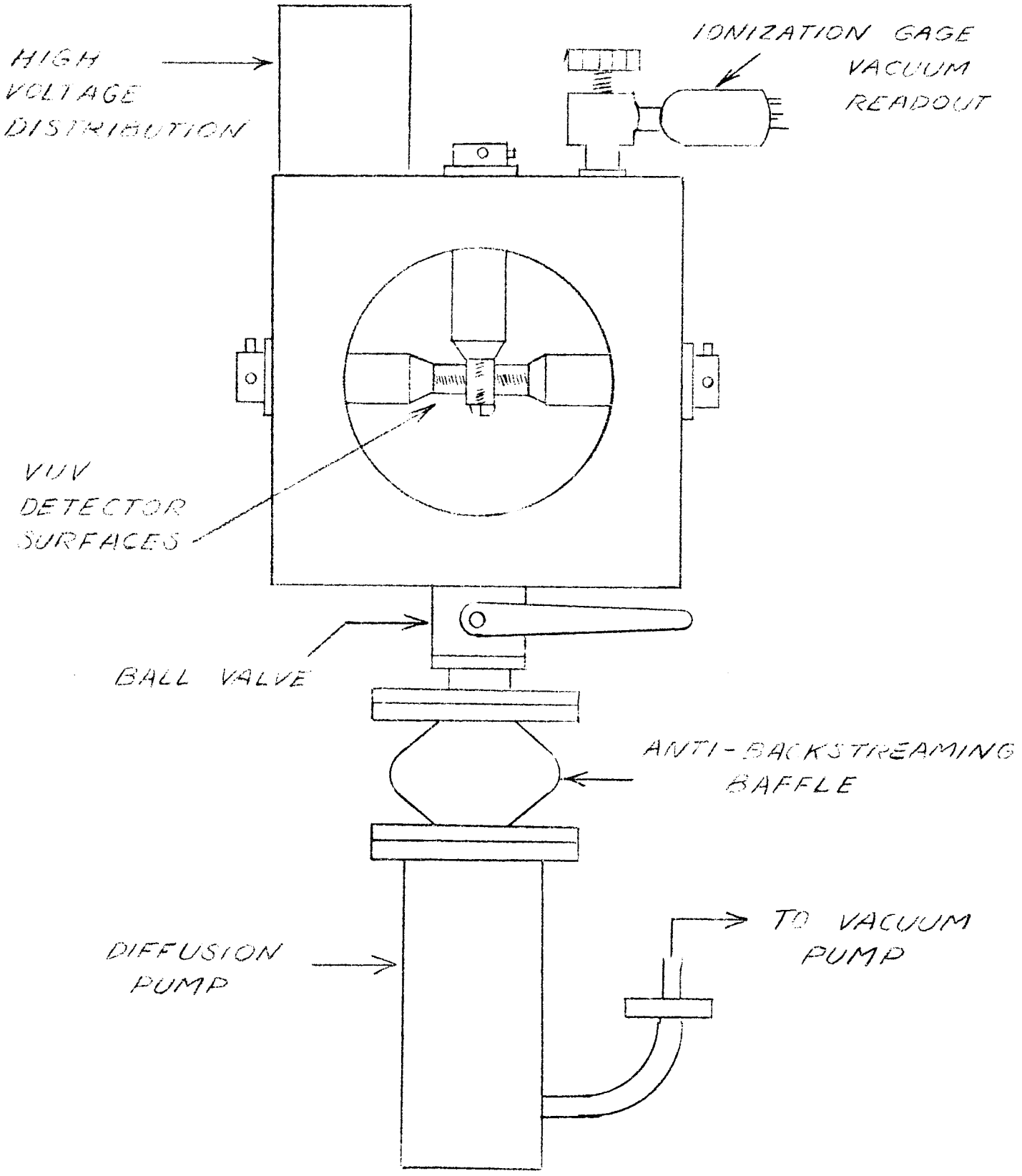

FIGURE 3 VUV DETECTOR ASSEMBLY