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RECENT PROGRESS WITH THE VORTEX STABILIZED ARC

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BY

STAN NEUDER
ROBERTA URSCHEL
ROY McINTOSH

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GODDARD SPACE FLIGHT CENTER
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Stan Neuder
Roberta Urschel*
Roy McIntosh*

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ABSTRACT

Spectroradiometric investigations of vortex stabilized, inert gas plasmas continue in order to achieve an improved spectral match. Results of recent measurements on argon, neon, and argon-neon plasmas are presented. A significant step towards the desired spectrum is achieved with certain argon-neon combinations. A description of the vortex arc and associated experimental apparatus is included.

RECENT PROGRESS WITH THE VORTEX STABILIZED ARC

1. Vortex Arc Description

Figure 1 is a sketch of the vortex stabilized source. The tungsten electrodes are axially positioned within two concentric quartz cylinders. The gas enters under pressure behind the anode section, passes between the cylinders and into the cathode. It is spirally injected into the inner chamber through nearly-tangential orifaces in the cathode wall and is exhausted through the central bore of the anode. The vortex restricts the plasma to well-defined cylindrical symmetry with typical dimensions of 2 mm diameter and 10 mm length. The exhaust gas is cooled in the heat exchanger and is continuously recirculated by means of compressors. Gas pressure may be increased to over 20 atm. There is no gas loss during operations and almost all is retrievable when desired.

The power input may be varied from about 3,000 to 25,000 watts with currents up to 250 amps readily obtainable. The electrodes and small cylindrical housing (not shown) are water cooled.

2. Instrumentation

Figure 2 is a block diagram of the experimental apparatus used for obtaining the spectral radiation data. The Leiss double prism monochromator is calibrated in the spectral range 0.25 to 2.4 microns.

The radiation is chopped at the entrance slit of the integrating sphere and detected by a photomultiplier or photoconductive cell. The signal is displayed on a strip chart recorder. The measured response is calibrated with a 1000 watt quartz iodine standard of spectral irradiance.

Figure 3 is a simplified sketch of the optical system. The calibrated filter is used only in the arc beam.

3. Plasma and Electrode Life

A typical stabilized argon plasma is shown in Figure 4. This is a 40 amp, 1.5 mm diameter column at 4 KW input and 8 atm. The diameter increases to 2.5 mm for a 200 amp plasma.

Electrode lifetime is quite high in argon. Figure 5 shows the cathode and anode following more than 100 hours of intermittent operation in argon at various current levels. The gas orifaces are clearly discernible in both.

Electrode lifetime is short in neon and helium plasmas. Electrodes following only a few hours in neon is shown in Figure 6 most of the tungsten loss from the cathode is deposited on the anode and inner quartz envelope.

4. Spectral Measurements

A. Argon—The relative spectral distributions of argon at 5 KW and 20 KW and 8 atm are shown in Figures 7 and 8. The spectra are combinations of continuum and line broadened emission. Comparison shows that the effect of increased current is manifested in increased ultraviolet content and an increased ratio of continuum to line emission.

For greater ease of comparison emission spectra has been replotted in terms of energy per unit bandwidth, as shown in Figure 9. The curves are that of argon at 16 atm, 5 KW and 16 atm, 20 KW. The energy redistribution is now evident.

The effect of increased pressure on a 20 KW argon plasma is shown in Figure 10. The pressure change from 8 atm to 16 atm results in a redistribution of emitted energy in the 2500A-5500A wavelength region. This redistribution was not found in a 5 KW argon plasma.

B. Neon—Spectral measurements on neon were made at 4 KW and 16 KW, and 10 atm. The emission is a combination of line and continuum. Most of the energy is radiated in the 5500A-7500A region as seen in Figure 11. A considerable change in spectral distribution was found primarily in the 3500A-5500A region for the two power settings.

C. Argon-Neon Mixtures—Figure 12 is the spectral energy distribution of argon at 5 KW and of neon at 16 KW, superposed on the solar distribution at air mass zero.

With respect to the Johnson curve, it is seen that the argon spectrum alone is deficient throughout the visible wavelength range but has an excessive of UV continuum and near IR line emission. The neon spectrum alone is deficient at all wavelengths below 5500A and above 8000A but has excessive emission between 5500A-7500A.

Several mixtures of neon-argon were tried. The results of a 50% Argon-50% Neon combination at 4 KW and 7 atm is shown in Figure 13. The 100% argon curve is included for comparison.

The spectral emission of the two gas plasma is basically that of pure argon. As expected from theoretical considerations, this was found for other neon-argon combinations having argon as the major constituent. In order to balance the excitation probabilities, a 90 Ne-10 Ar combination at 4 KW and 4 atm was tried. This is shown in Figure 14. Again, direct comparison may be made with the included curve of pure argon at 5 KW and 4 atm.

The near IR transition of the first electronic excitation levels of both components appear equally likely in the 90-10 distribution at the 4 KW setting. Transitions from the second excitation levels of argon are still present but considerably weakened.

The most favorable result of this series was obtained with a 80% Ne-20% Ar plasma. Figure 15 compares an 80 Ne-20 Ar, 4 KW plasma with 100% Ar 5 KW plasma. Both are superposed on the solar distribution.

CONCLUSIONS

Adjustments have been made in the spectral energy distribution and continuum to line emission ratio by varying the plasma current and ambient pressure. Adjustments in the spectral emission intensities, at fixed plasma currents have been accomplished statistically.

Although a proper neon-argon combination presents an improved spectral match above that of the individual components alone, it is still deficient, (at least at the lower power and pressure levels), in the 4000A-6000A region. Based on theoretical considerations and experimental results obtained, it is felt that further improvements in the spectral match will be achieved by (a) increased power input at different pressure ambients and (b) the presence of other gaseous components in the plasma.

These two approaches will be pursued.

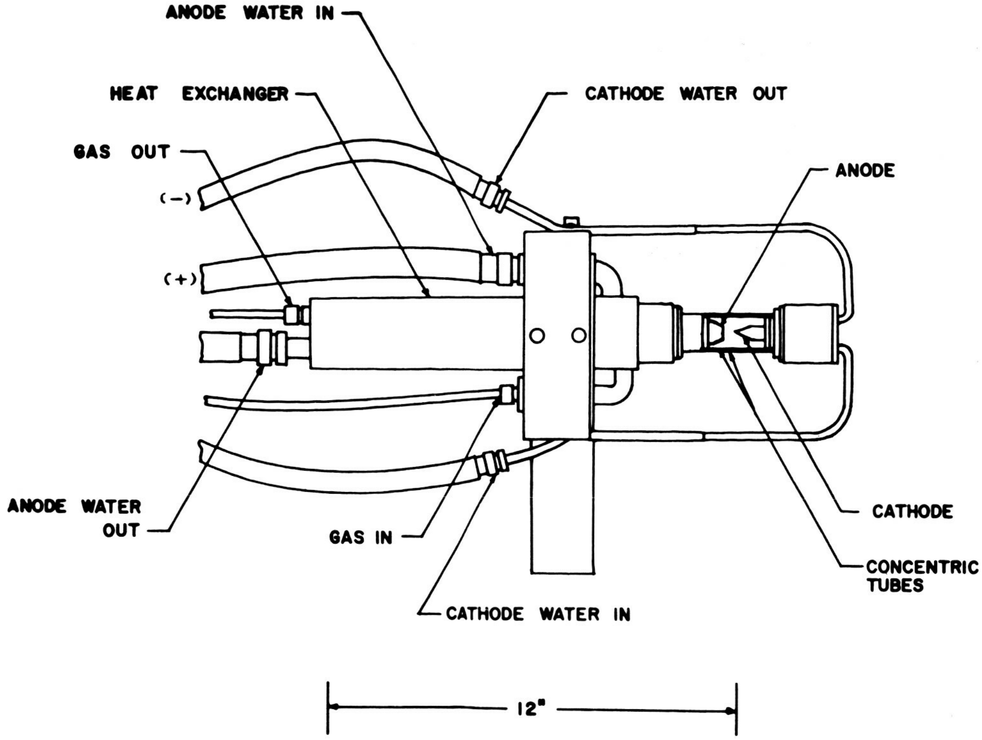

Figure 1. Vortex arc

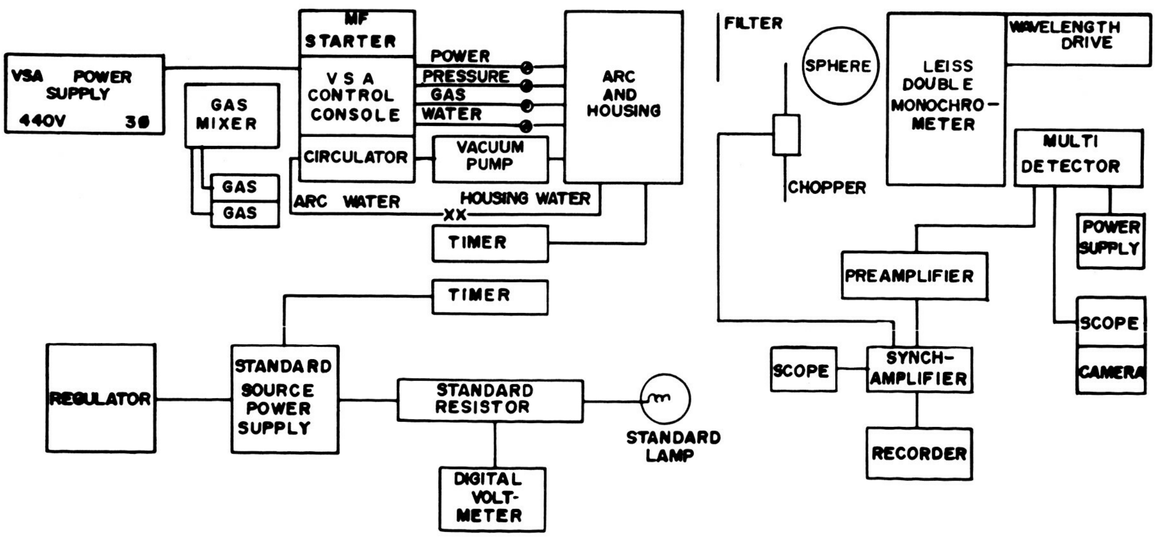

Figure 2. Instrumentation

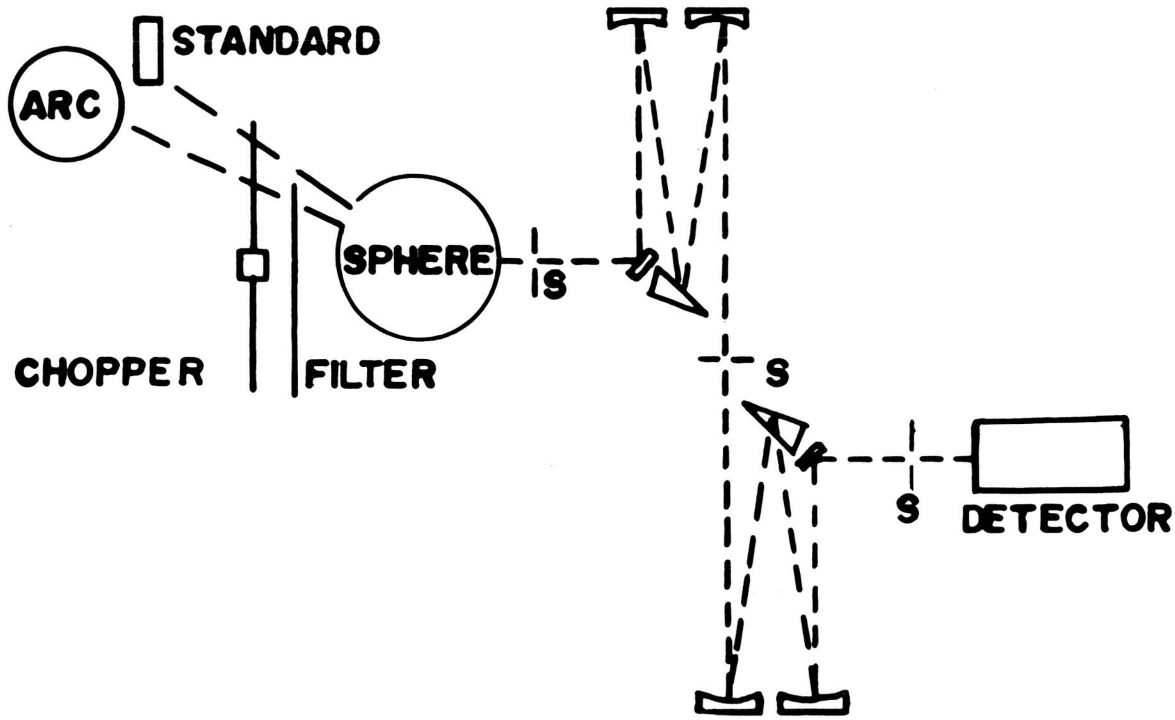

Figure 3. Optical system

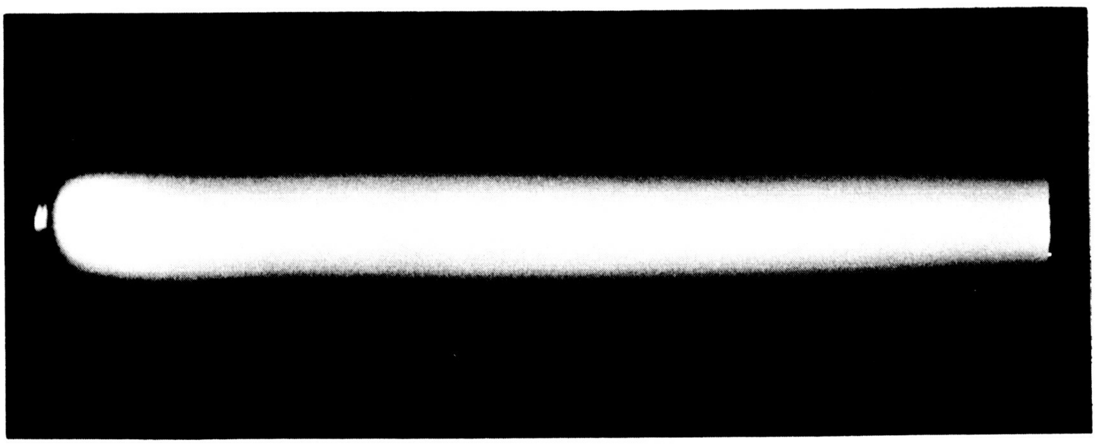

Figure 4. Argon plasma 4 KW, 8 atm, 40 amps

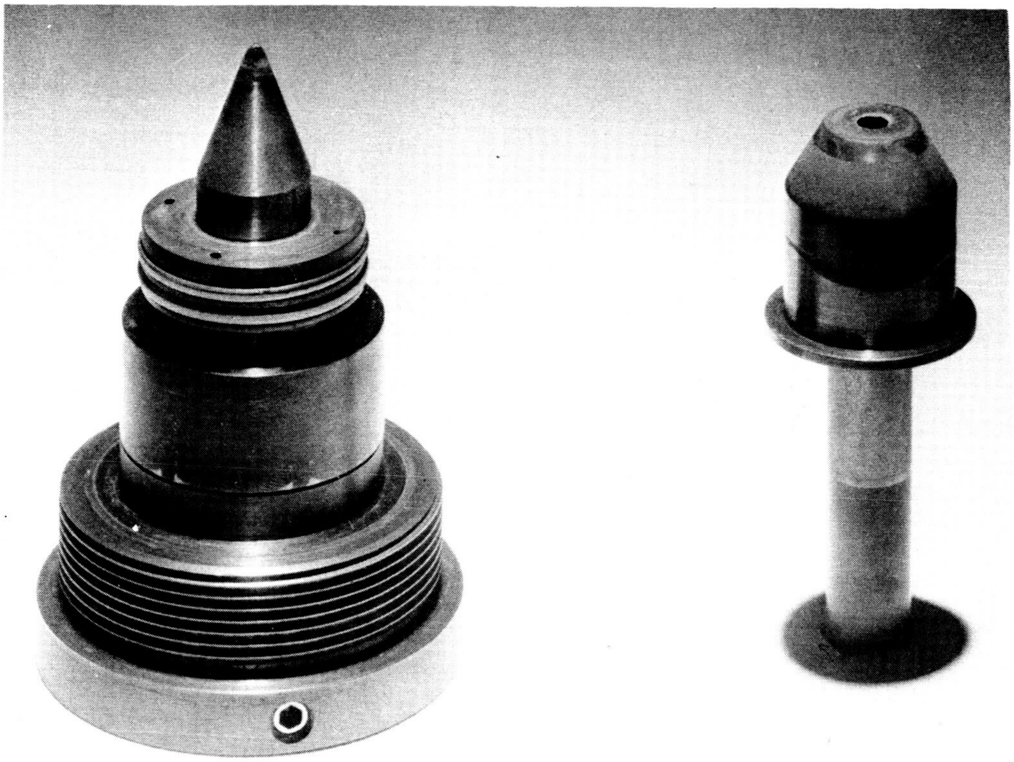

Figure 5. Electrodes after 100 hrs. in Argon

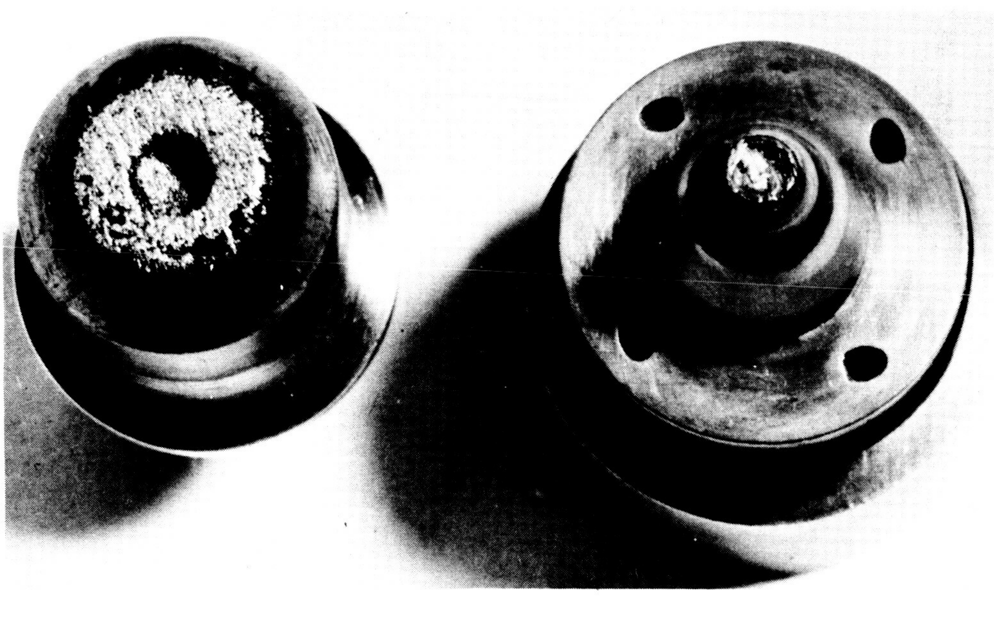

Figure 6. Electrodes after a few hrs. in Neon

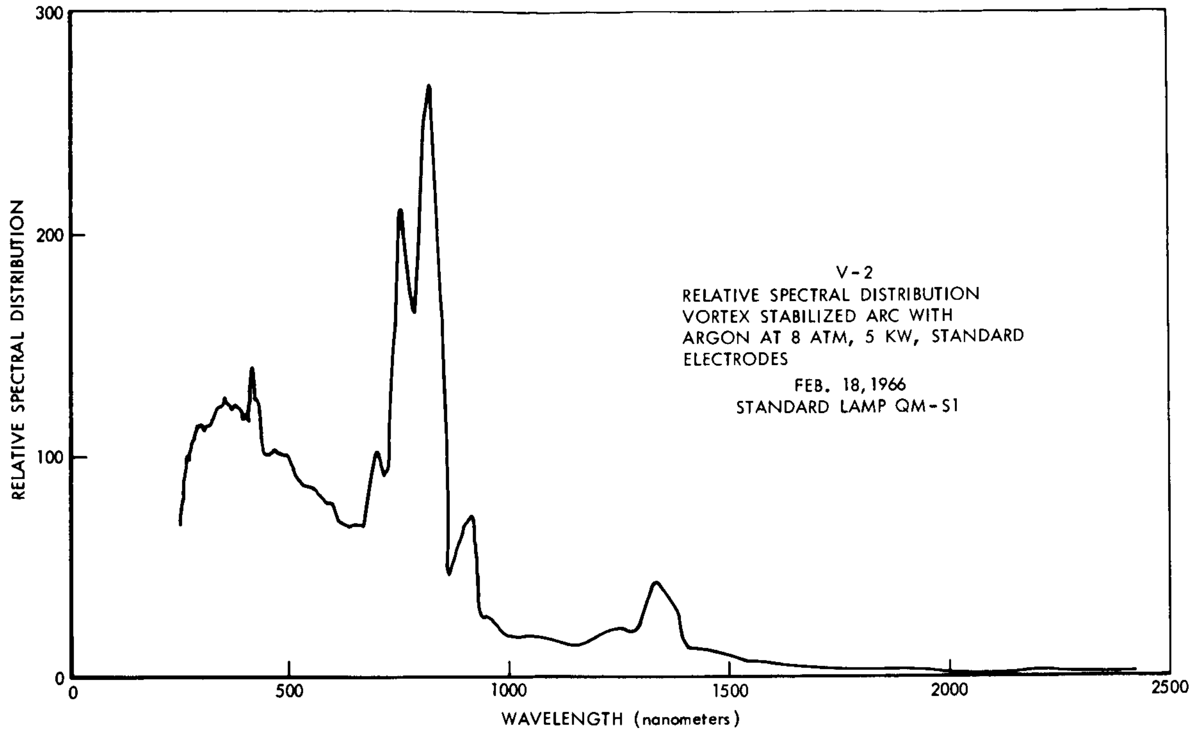

Figure 7. Argon spectral distribution at 5 KW

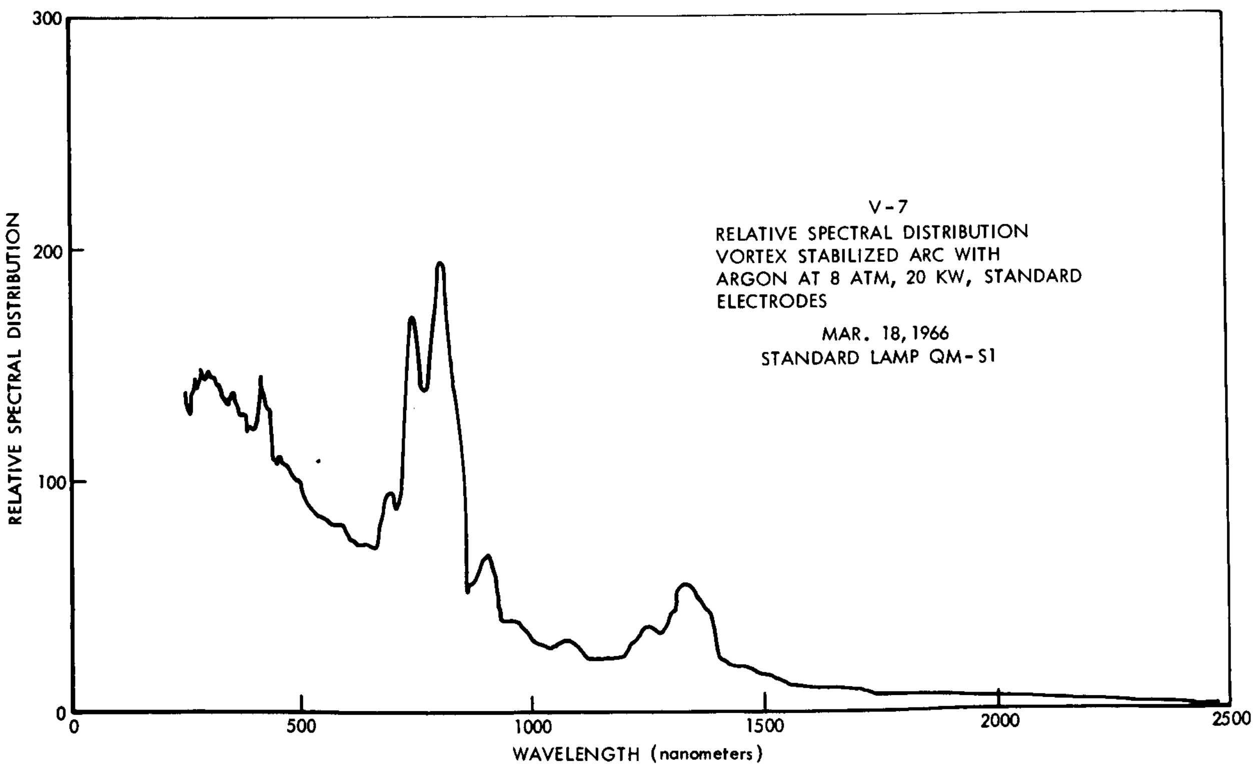

Figure 8. Argon spectral distribution at 20 KW

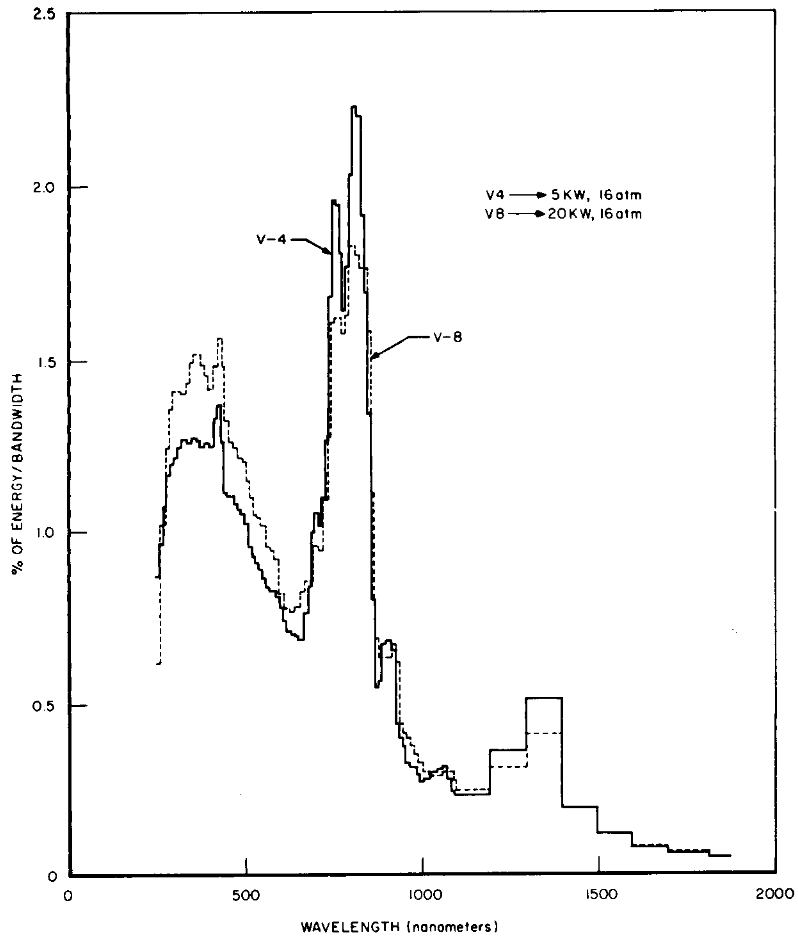

Figure 9. Argon at 5 KW and 20 KW

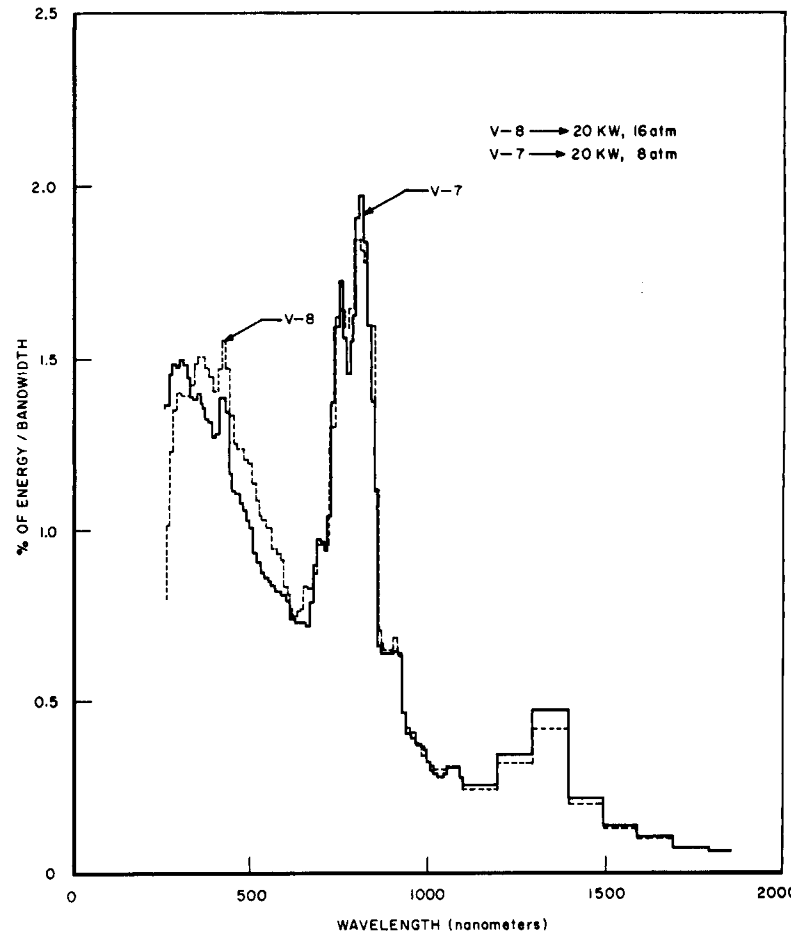

Figure 10. Argon at 8 atm and 16 atm

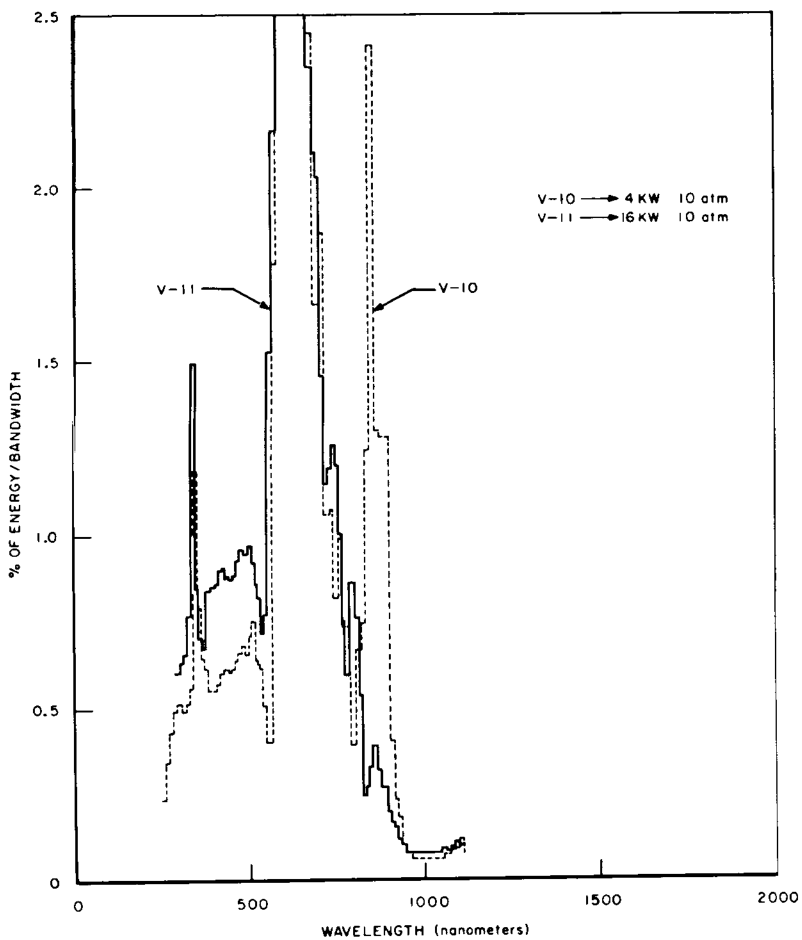

Figure 11. Neon at 4 KW and 16 KW

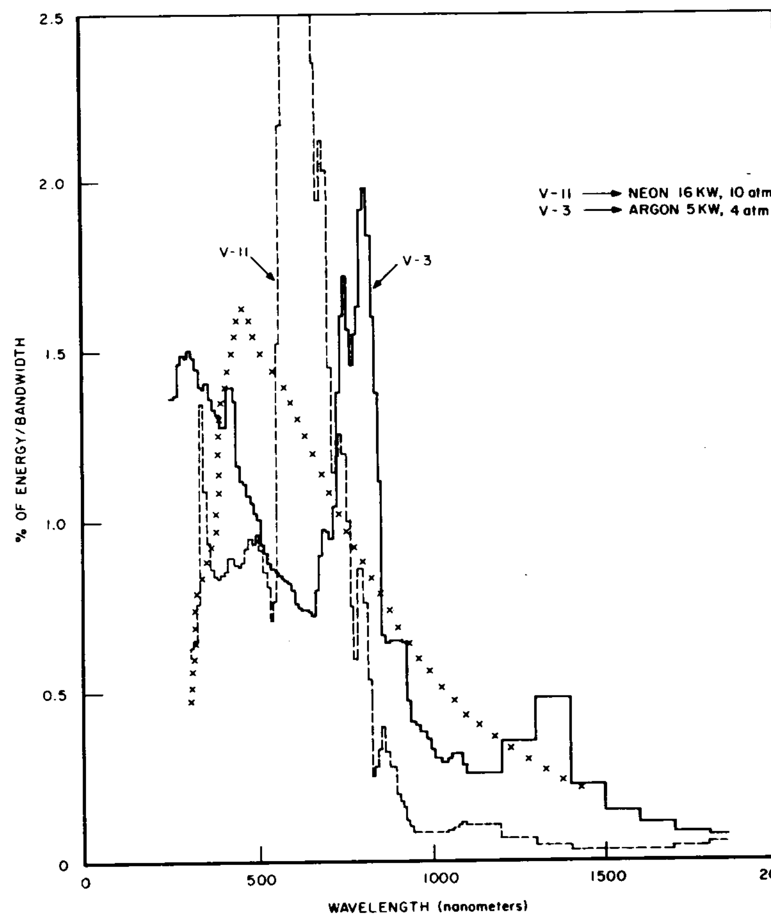

Figure 12. Neon at 16 KW, Argon at 5 KW,
and the solar distribution

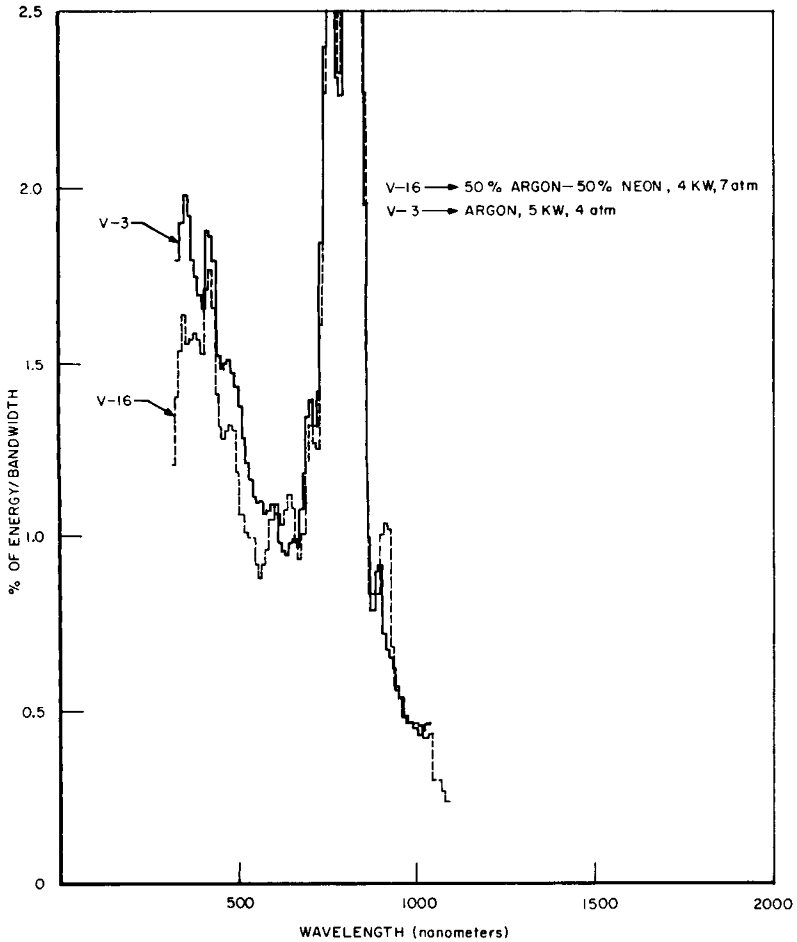

Figure 13. 50% Ar–50% Ne at 4 KW, and 100% Ar at 5 KW

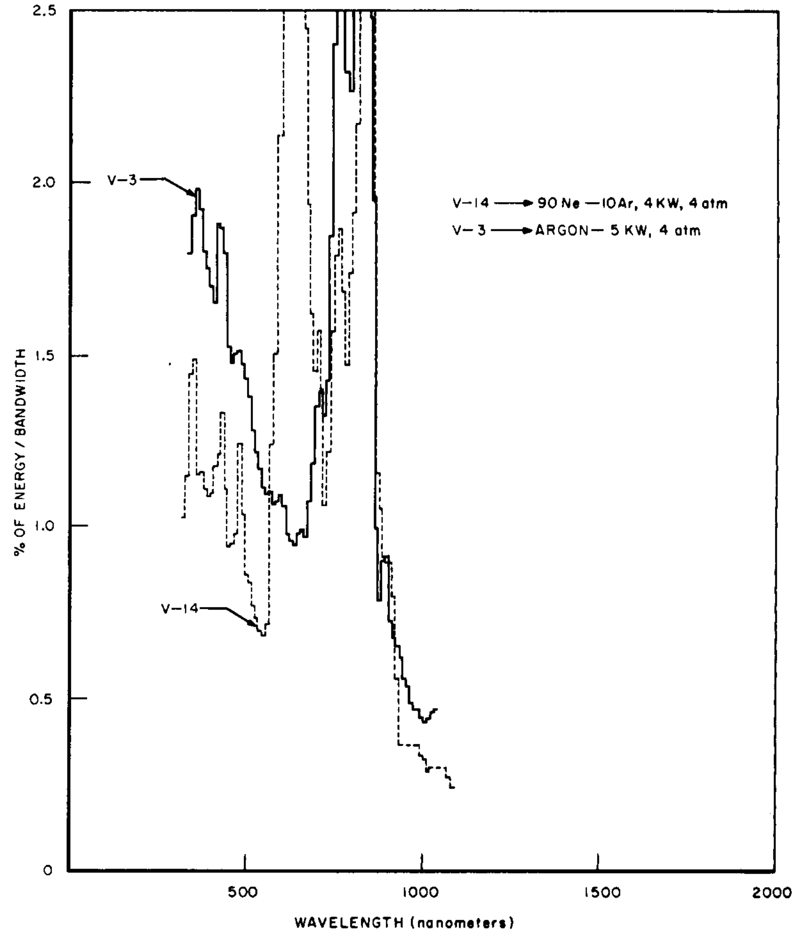

Figure 14. 90% Ne–10% Ar at 4 KW and 100% Ar at 5 KW

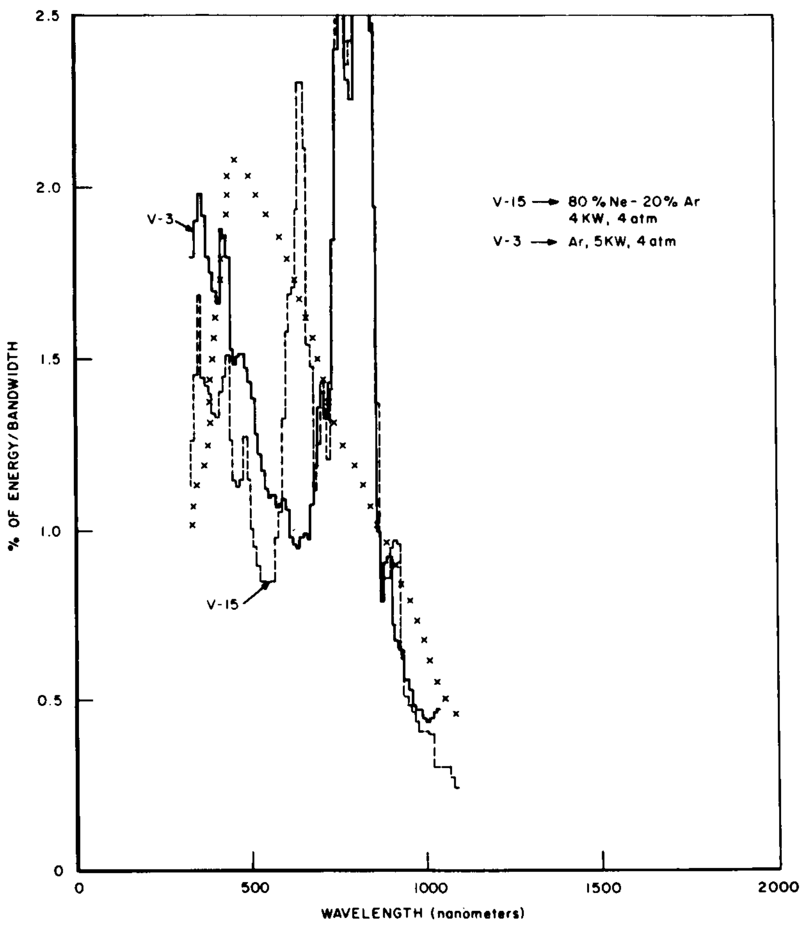

Figure 15. 80% Ne–20% Ar at 4 KW, 100% Ar at 5 KW and the solar distribution