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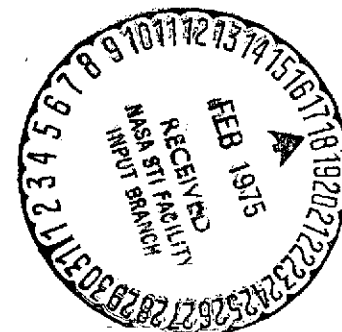
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VISIBLE SPECTRAL POWER EMITTED FROM A LASER-PRODUCED URANIUM PLASMA

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16. Abstract NASA is involved in a program to establish the scientific and engineering knowledge required for the development of plasma-core nuclear reactors for advanced terrestrial and space-power sources. These reactors will release their energy primarily in the form of light. Since the core material may be contained in a quartz enclosure, the power and operational characteristics of the reactor may be greatly dependent on the magnitude and spectral distribution of radiation within the wavelength band, 0.2 to 4.0 micrometers. The magnitude and spectral distribution of radiation from a simulated non-fissioning core plasma has been measured within the band of interest. The results are expected to contribute to the understanding and development of plasma-core reactors. ORIGINAL PAGE IS OF POOR QUALITY			
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VISIBLE SPECTRAL POWER EMITTED FROM A LASER-PRODUCED
URANIUM PLASMA

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NASA is involved in a program to establish the scientific and engineering knowledge required for the development of plasma-core nuclear reactors for advanced terrestrial and space-power sources. These reactors¹ will release their energy primarily in the form of light. A fused-silica enclosure may be used to contain the fissioning material. Thus the power radiated through the enclosure will be limited in wavelength to the band between 0.2 and 4.0 micrometers. The magnitude and the spectral distribution of core radiation will determine, respectively, the power available from the core and the transmission efficiency of the enclosure. Both of these aspects of core radiation depend critically on the kind of radiative equilibrium, if any, established in the core.

Experimental measurements of the intensity and the spectral distribution of radiation from a nonfissioning uranium plasma are reported here. The measurements provide an estimate of radiation power, insight into the equilibrium character of the plasma, and a basis for a future determination of effects of fissions on the radiation characteristics of similar uranium plasmas.

The experimental arrangement was basically the same as that reported in a previous paper.² A ruby laser pulse was focused on the flat surface of a pure U^{238} sample to create a plasma plume which expanded perpendicular to the sample surface. The sample was located such that the spectrograph viewed the edge of a disk-shaped section of the plasma plume. The disk-shaped cross section was parallel to the sample surface. An auxiliary slit was used near the sample

surface to limit the width of the observed cross section edge to 0.5 mm. A half-meter spectrograph/scanning monochromator (McPherson model 216.5) was used to produce a spectrum of the plume radiation. It contained a 1200-line/mm grating that was blazed for peak radiation at 0.5 μm in the first order. All optical surfaces in the spectrograph were coated with magnesium fluoride. Calibrated stop-band filters were used in the spectrograph to eliminate multiple-order diffraction of radiation into wavelength regions above 0.4 μm . Amperex 150 CVP (S-1) and 150 UVP (S-20) photomultiplier tubes were used to detect and time resolve spectral radiation from two different sections of the plasma plume. The 150 CVP observed a plume cross section centered 0.25 mm from the sample surface and the 150 UVP observed a cross section centered 0.75 mm from the sample surface. The photomultiplier tubes observed 8 \AA portions of the spectrum at wavelength intervals from 25 to several hundred angstroms throughout the wavelength interval. Electrical pulses from the photomultiplier tubes were displayed on a Tektronix type 7904 oscilloscope and recorded on polaroid film. Neutral density filters were used to check the linear relationship between the electrical pulses and light intensity.

A carbon arc was used to determine the absolute intensity of spectral radiation detected by the phototube/spectrograph combination. The anode spot of the arc was focused at the position of the laser plasma in front of the spectrograph's entrance slit. To maintain the phototube's gain, the carbon arc light was mechanically chopped into pulses. Output pulses were amplified approximately 640 times and displayed on an oscilloscope having a 12 sec/cm sweep speed. By simultaneously running the spectrograph's wavelength drive at one and two thousand angstroms per minute, the carbon arc spectrum was traced on the oscilloscope with reciprocal dispersions of 200 and 400 angstroms per

centimeter. Time exposures of the traces recorded the arc spectrum on polaroid prints.

The laser pulse was a symmetric Gaussian with a full width at half maximum intensity equal to approximately 20 nanoseconds. The plasma pulse intensity was a much wider Maxwellian (>200 ns at half maximum intensity). All data for plasma intensity plotted in figures 1 and 2 were measured at the peaks of the photomultiplier signals. Actually, the spectrum changes at each instant of time so the time of the signal peak at each wavelength varied on the order of ± 10 ns from the average time. Thus, the spectrum intensity measured at a particular time equal to the average time of the signal peaks could be a few percent smaller than the plotted intensities.

In figure 1 the peak of the phototube signal at approximately 3600 \AA was caused by a combination of a peak in the photomultiplier tube response and the plasma intensity which increases rapidly toward shorter wavelengths. The sharp cutoff at lower wavelengths is due primarily to a plastic window used with the phototube. At 5000 \AA the slight peak was probably due to the blaze of the grating. Intensity measurements were made beyond 7000 \AA to $10,000 \text{ \AA}$. They revealed a second-order intensity peak at 7200 \AA . (The peak could be removed by a filter which stopped radiation at 3600 \AA .) Otherwise, the spectral intensity decreased smoothly toward zero. The same spectral features were recorded when the same phototube was used to observe the cooler and less dense plasma 0.75 mm from the sample surface. However, average intensity decreased by approximately an order of magnitude.

Another phototube (150 UVP)/window combination was used to record the measurements of figure 2. It provided increased sensitivity and extended readings

to shorter wavelengths. The phototube data confirm the absence of the radiation peak in the 3600 Å region of figure 1.

In figures 1 and 2 the carbon arc data show emission peaks superimposed on the continuum, especially at 3600 Å and 3800 Å. These peaks were caused by molecular radiation from the arc in front of the anode spot. To eliminate the peaks from the calibration a smooth curve was faired through the continuum with the aid of a digitizer, computer, and plotter. The phototube current represented by the smooth curve was divided into the phototube current generated by the plasma signal throughout the spectrum. This spectral ratio was similarly multiplied by the known spectral intensity³ of the carbon arc to obtain the calibrated spectral intensities.

Figures 3 and 4 compare the calibrated emission curves with blackbody emission curves. Figure 3 illustrates that within 0.5 mm of the uranium surface emission conforms very closely to that of a blackbody at a temperature of 38,600 K. In figure 4 the spectrum emitted 0.5 - 1.0 mm from the sample surface is compared to a 38,600 K blackbody that has a directional spectral emissivity of 0.04. At 0.5 - 1.0 mm from the sample surface the emission deviates markedly from blackbody emission, especially toward smaller wavelengths.

Based on the experimental measurements of others,⁴ the plasma ion density 0.25 mm from the sample surface was of the order of 10^{20} cm⁻³. At 0.75 mm the density was an order of magnitude less and had a much larger variation through the 0.5 mm thickness of the observed cross section. Previous vacuum UV measurements² indicate the highest temperature in the densest portion of the plasma to be about 38,600 K. For these conditions local thermodynamic equilibrium existed in the plasmas as is illustrated by the calibrated intensity curves which have the spectral character of blackbody emission. These spectra should be useful

for comparison with the spectra produced by future fissioning uranium plasma experiments to determine the spectral effects of fission fragments and to provide spectral data for plasma-core nuclear-reactor design studies.

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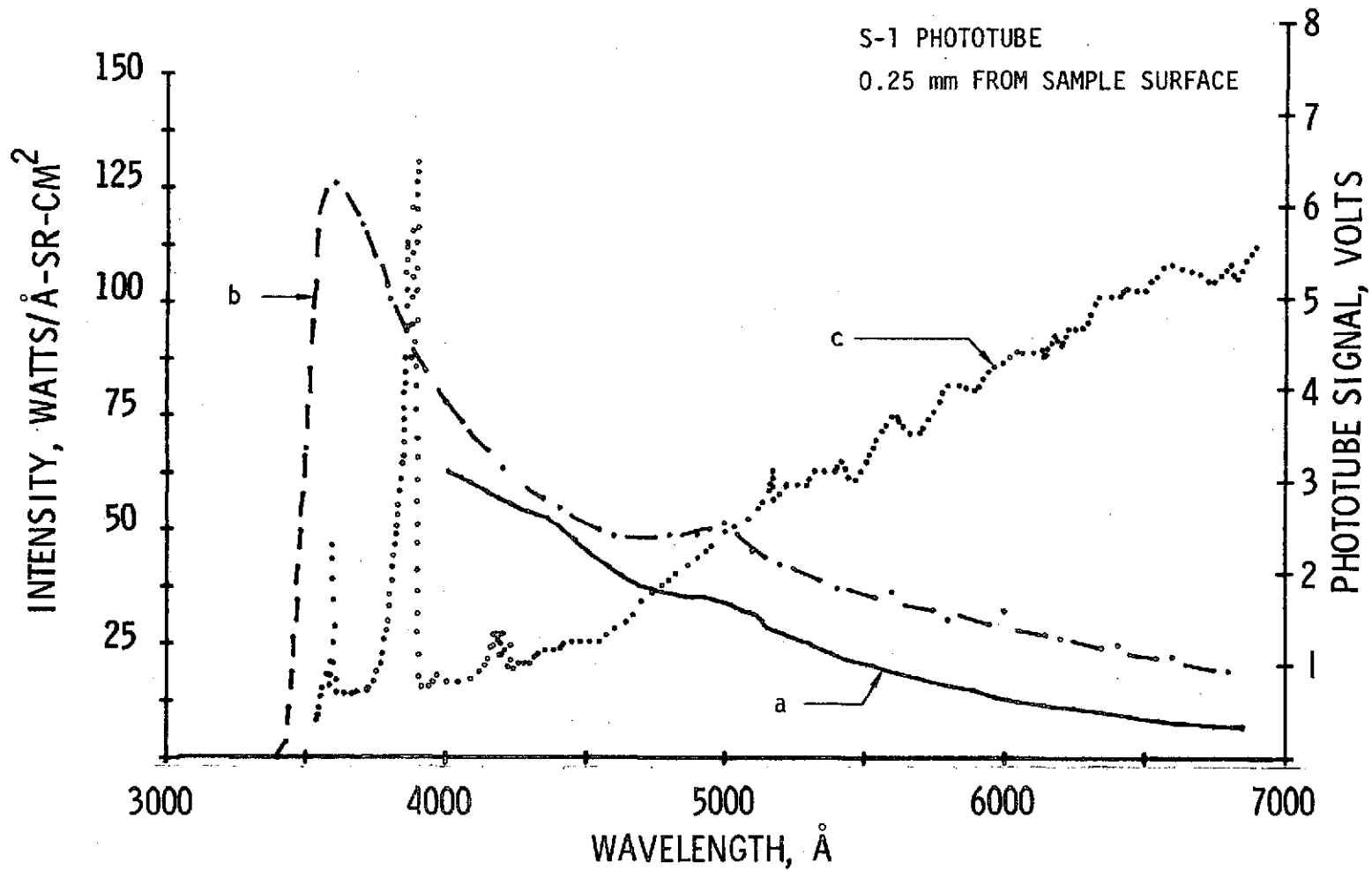


Figure 1.- Spectra of uranium plasma and carbon arc. (a) Calibrated and time-resolved spectrum of uranium plasma 0.25 mm from sample surface; (b) phototube data scaled in volts; (c) unscaled carbon arc spectrum.

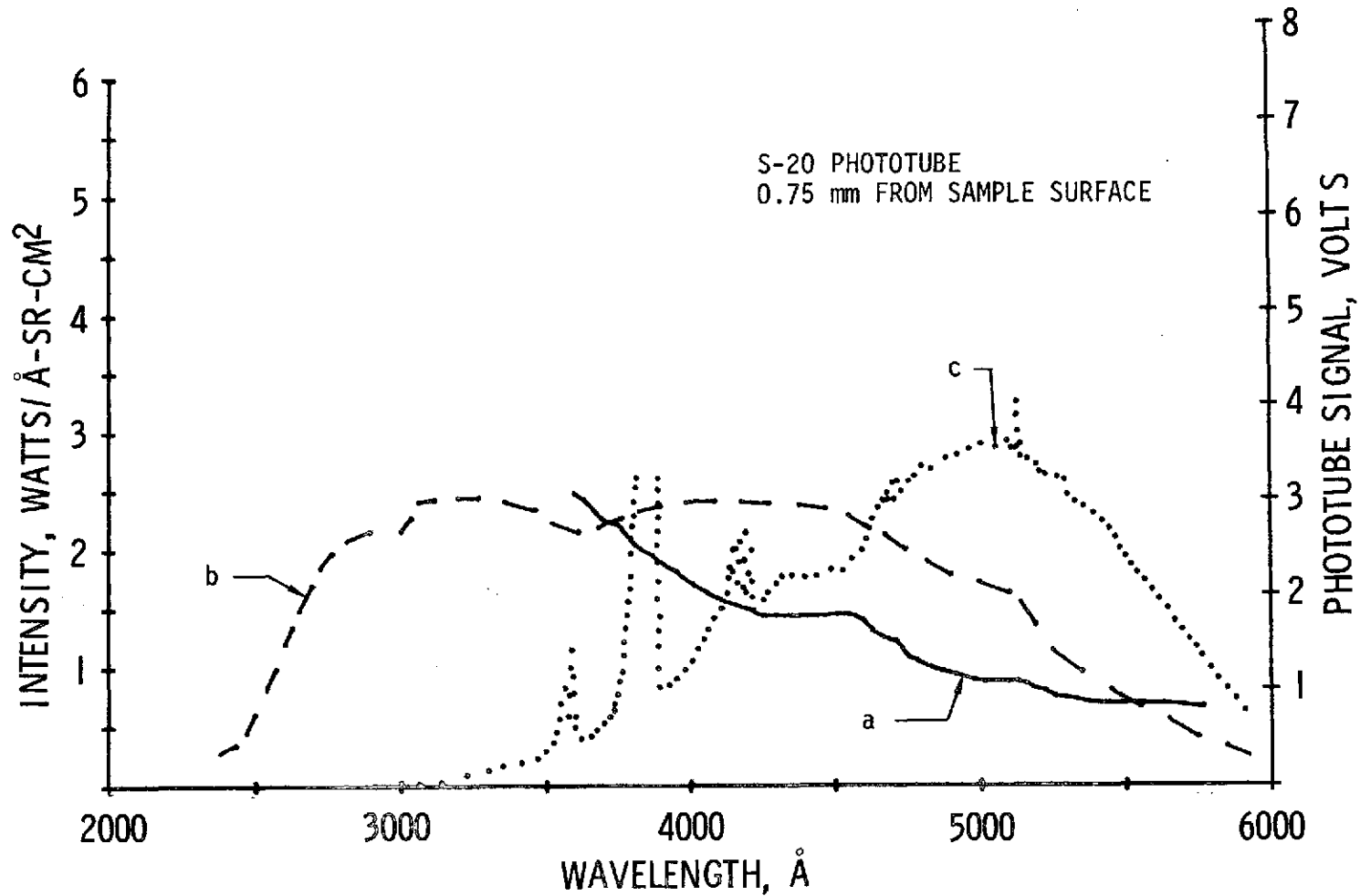


Figure 2.- Spectra of uranium plasma and carbon arc. (a) Calibrated and time-resolved spectrum of uranium plasma 0.75 mm from sample surface; (b) phototube data scaled in volts; (c) unscaled carbon arc spectrum.

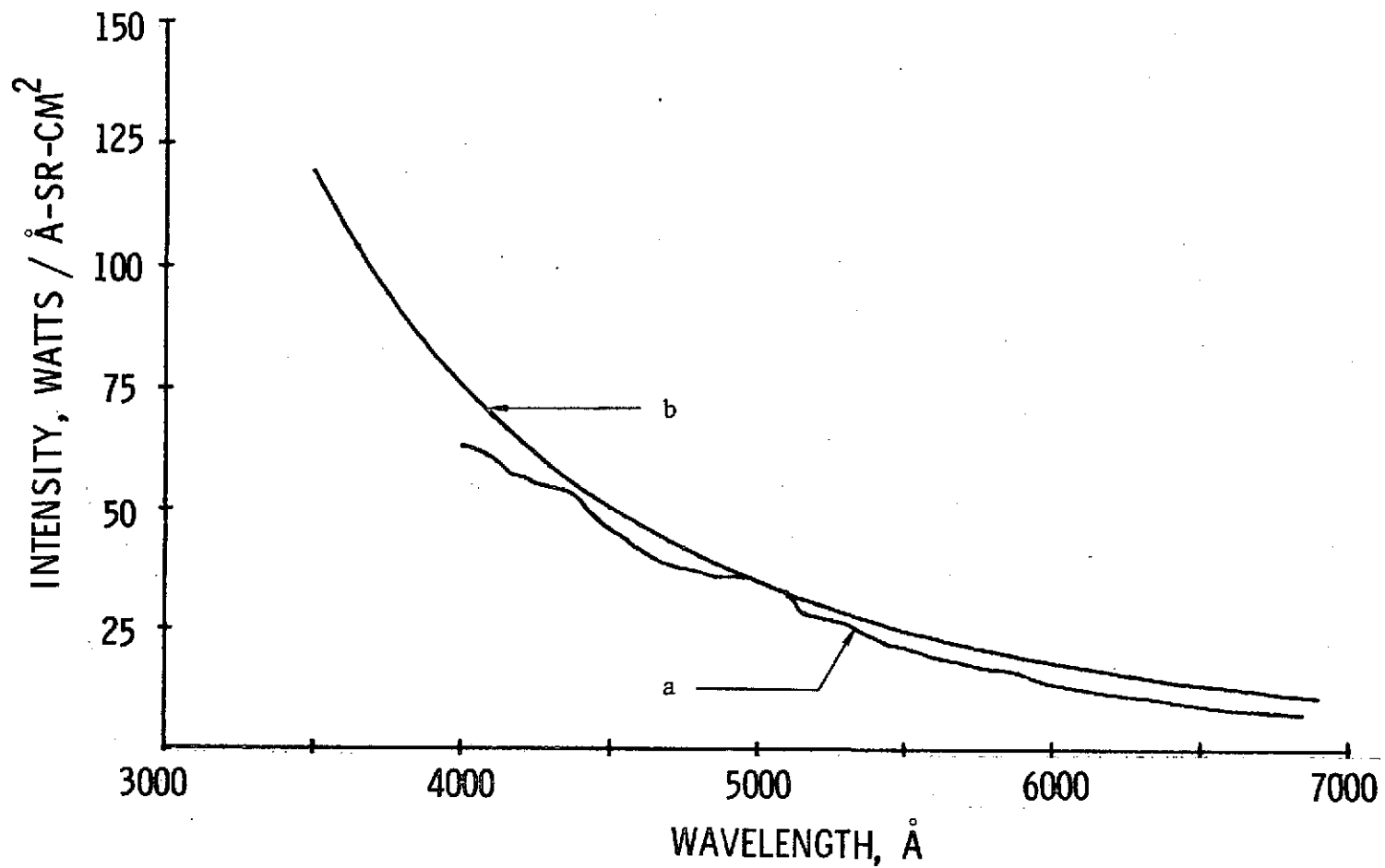


Figure 3.- Comparison of uranium plasma and blackbody emission.
(a) Calibrated uranium spectrum 0.5 mm from sample surface;
(b) spectrum of 38,600 K blackbody.

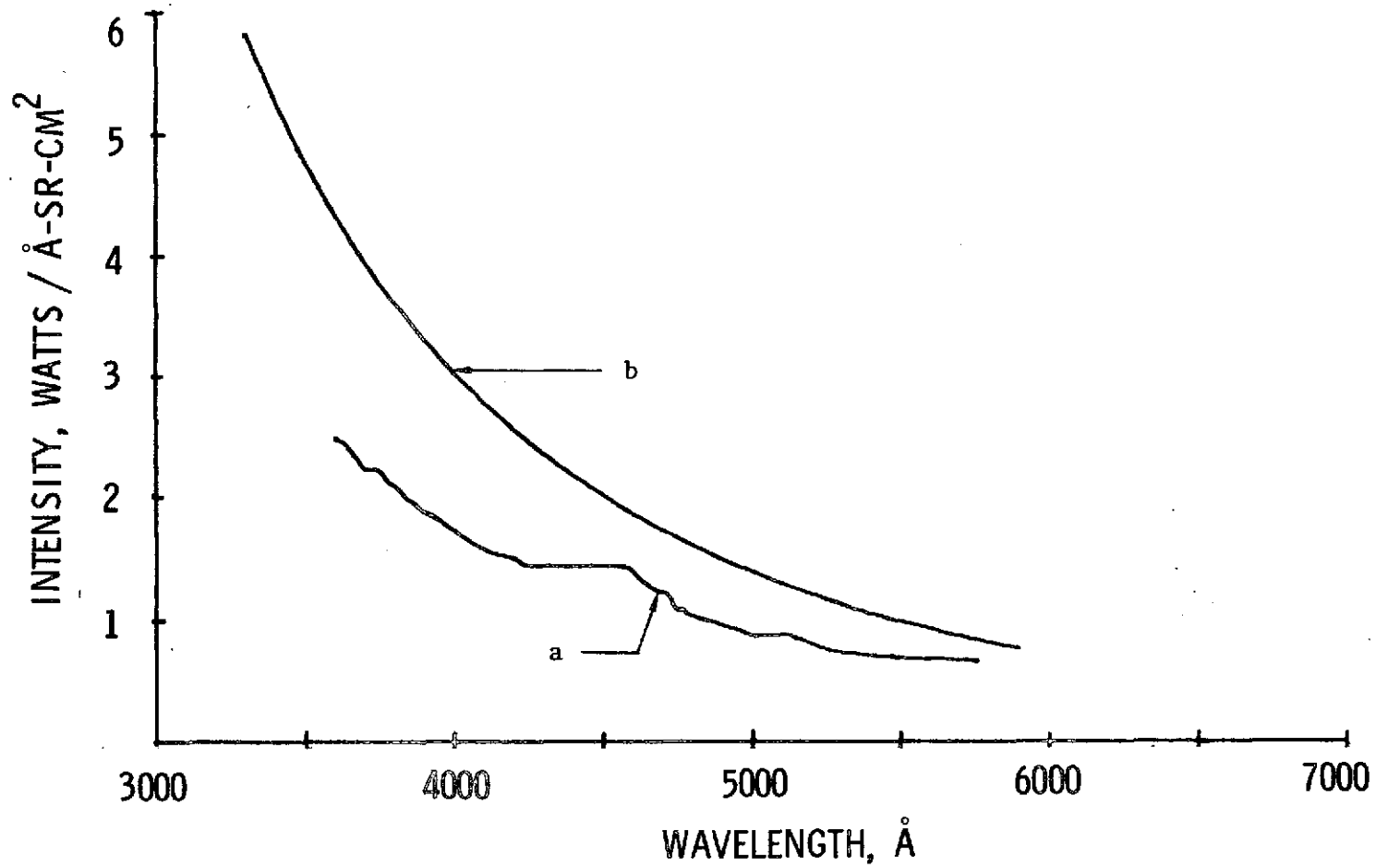


Figure 4.- Comparison of uranium plasma and blackbody emission.
(a) Calibrated uranium spectrum 0.75 mm from sample surface;
(b) spectrum of 38,600 K blackbody with 0.04 emissivity.