within the above pipe is throughout negative (below atmospheric) and constant, the relatively very large positive pressures exist within the pin-hole probe and its appurtenances (quill tube and U-gauge).

* Advance note from a Report to the Carnegie Inst. of Washington, D. C.

A COMPARISON OF THE THERMIONIC AND PHOTOELECTRIC WORK FUNCTIONS FOR CLEAN TUNGSTEN

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In Richardson's thermionic equation

$$i = A\ T^{\frac{1}{2}} e^{\frac{-\phi}{kT}}$$

and in Einstein's photoelectric equation

$$\frac{1}{2}mv^2 = h\nu - \phi$$

ϕ is interpreted as the work necessary to carry an electron from the interior of the metal to a position outside beyond the influence of the image force. If we assume the electrons to be conduction electrons in both cases, the ϕ's should be identical, if measured at the same temperature.

The complete agreement of experiment with the thermionic equation has justified the assumption there, and Millikan[1] has shown that it is valid in photoelectric emission. However, no convincing experimental confirmation of the identity of the ϕ's has been found heretofore.

Such an experiment must be made on a metal surface, as free as possible from gas and impurities. High temperatures are necessary in order to free the metal from gas and, consequently, only tungsten, tantalum, molybdenum, and possibly platinum, are suitable. Tungsten admits of the highest temperatures and was consequently chosen for this work.

Previous Work.—Woodruff,[2] working with platinum, found that the thermionic work function was abnormally high when the specimen was insensitive photoelectrically. It is doubtful whether he had clean surfaces, however, since the thermionic work function was not the same for increasing as for decreasing temperatures, and the photoelectric sensitivity changed with time.

Harrison[3] measured the two work functions for a tungsten filament, but had the same difficulties that Woodruff found with platinum. The thermionic work function was not the same for increasing as for decreasing temperatures. When the filament was heated and then allowed to stand at room temperature, the photoelectric sensitivity was at first quite small, but increased to large values after several days, or immediately upon the removal of liquid air from a trap. In the sensitive condition the work function was 4.57 volts (2700 Å). The thermionic work function varied between 4.8 and 6.5 volts.

Hamer[4] used a tungsten plate, which he sandpapered before mounting. He made no attempt to clean the metal by heating, and worked at pressures of the order of 1/100 mm. of mercury. He gives 4.72 volts (2615 Å) for the photoelectric work function, but did not measure the thermionic.

Hagenow[5] heated a pure tungsten plate to a bright orange-yellow and obtained a value between 5.89 (2100 Å) and 5.36 (2300 Å) for the photoelectric work function at room temperature. He found the surface only slightly sensitive, and was forced to use filters with the full light from the quartz mercury arc in making the determination. He did not measure the thermionic value.

S. C. Roy[6] has measured the variation of the total photoelectric current as a function of the temperature of the illuminating source. He finds that it obeys the equation

$$i = A\,T^{\frac{1}{2}}\,e^{\frac{-n\nu_0}{kT}}$$

where ν_0, the limiting frequency for the photoelectric effect, corresponds to 4.57 volts (2700 Å). He heated this specimen to a red heat and worked at quite low pressures. All the leads were brought into the tube through wax seals. The presence of any wax vapors has been found to greatly influence the thermionic work function, and consequently would be expected to effect the photoelectric. He did not measure the thermionic work function.

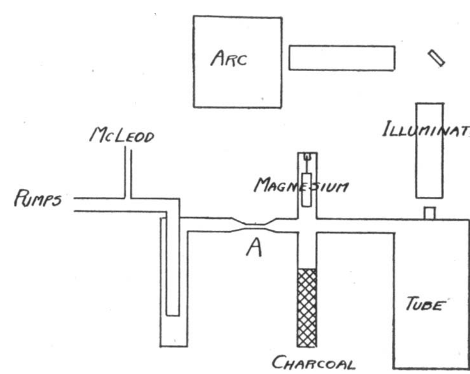

FIGURE 1

Using carefully purified tungsten, Davisson and Germer[7] have found the thermionic work function for tungsten to be 4.778 volts (2580 Å).

Dushman[8] gives the value 4.54 volts (2690 Å).

None of the photoelectric work above has been done under the extreme vacuum conditions that have been found necessary in the thermionic determinations. Langmuir[9] has shown that it is necessary to eliminate all wax vapors, bake out all glass thoroughly, and bring all metal parts to a white heat. The author has also found that the presence of a "getter" is necessary for consistent results at temperatures below 2100°K. In the present work, consistent, reproducible thermionic results were first obtained, before any photoelectric measurements were made.

Apparatus.—All glass parts of the apparatus where of Pyrex. A graded seal from Pyrex to quartz was used to attach a quartz window. All leads through the glass were of tungsten. The arrangement of the apparatus is shown in figure 1. The arrangement of the photo-electric tube is shown in figure 2.

The tungsten specimen was a loose conical spiral of commercial ten mil wire, spot welded to tungsten leads. A platinum Faraday cage surrounded this, and was connected to a Dolezalek electrometer having a sensitivity of 1300 mm. per volt at 150 cm. scale distance. The electrical connections are shown in figure 3.

Illumination was from a quartz mercury

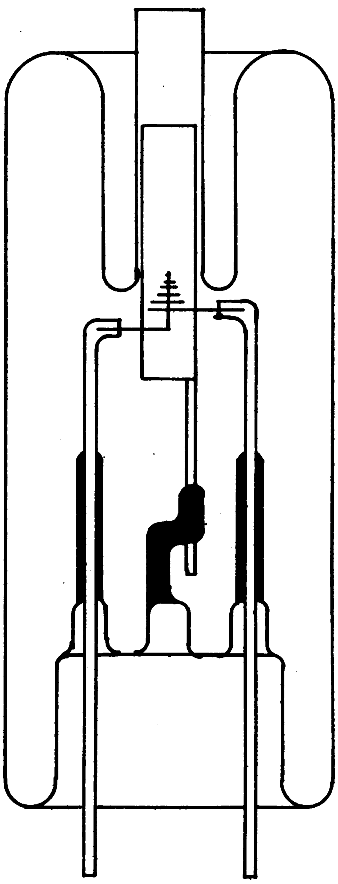

FIGURE 2

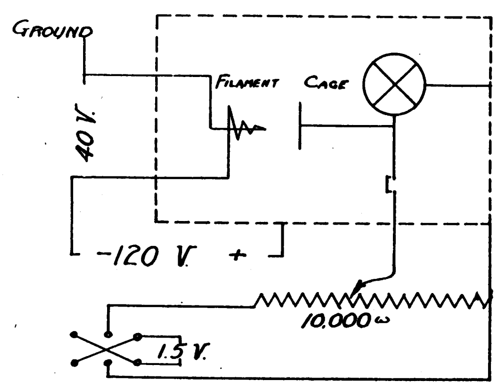

FIGURE 3

arc operating at 93 volts 2.5 amperes and 200°C. The energy distribution of such an arc has been measured by Kazda[10] in this laboratory. A Hilger mono-chromatic illuminator directed the light upon the spiral.

Results.—The tube and charcoal were baked at 500°C. for five hours. The tube was cooled and the filament glowed at 2500°K. for twenty-four hours, while the charcoal was kept at 500°C. The Faraday cage was heated to a bright yellow for ten minutes. Before installation the cage was kept for ten minutes at a white heat in a high vacuum. The tube was again heated to 500 °C. for two hours. While tube and charcoal were hot the magnesium was heated sufficiently to coat the surrounding glass. Tube and charcoal were allowed to cool, the filament and Faraday cage were reheated for a short time, and the tube sealed off the pumps at "A," figure 1. Magnesium was again vaporized and liquid air placed around the charcoal.

A filament current-temperature curve for the central turn of the spiral was made. Temperatures were measured by means of a Leeds and Northrup optical pyrometer. The transmission of the quartz window had been measured previously.

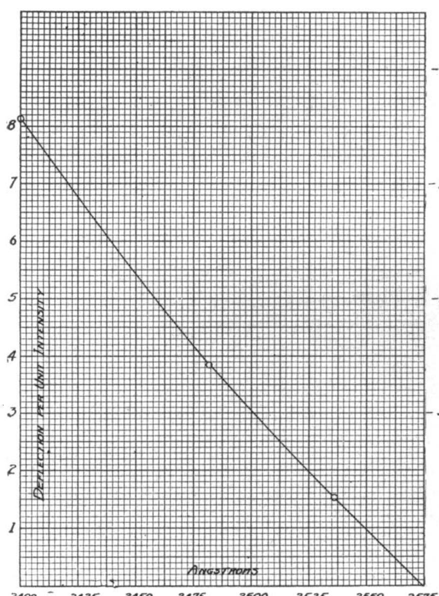

FIGURE 5

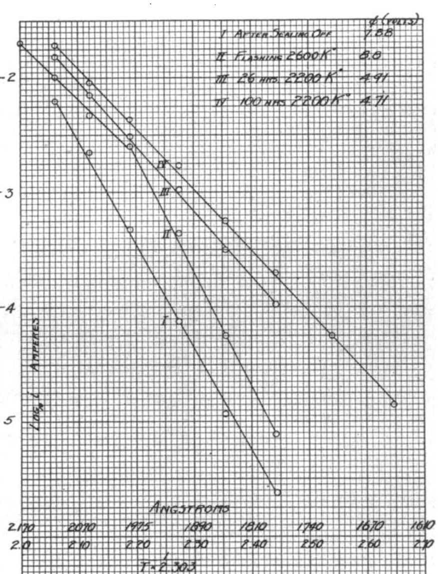

FIGURE 4

The filament was aged for 100 hours at 2200 °K. with 20 milliamperes thermionic current to the Faraday cage. Measurements of the thermionic work function was made at intervals. Several of these are shown in figure 4. The values of the emission were corrected for end losses by the method of Forsythe and Worthing.[11] The final value of the work function was 4.71 volts (2620 Å).

Thermionic emission practically ceased at 1100 °K., so at that temperature the photoelectric current was measured for the lines 2400, 2482 and 2536. The current per unit intensity is plotted against wave-length in figure 5. The photoelectric work function so found is 4.79 volts (2575 Å).

Conclusion.—The thermionic and photoelectric work functions for clean *tungsten have been measured, and are found to be identical within the experimental error.*

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[3] Harrison, *Proc. Phys. Soc., London*, **38**, 1926 (214).
[4] Hamer, R., *J. O. S. and R. S. I.*, **8**, 1924 (251–257).
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[7] Davisson, C., and Germer, L. H., *Physic. Rev.*, **20**, 1922 (300–330).
[8] Dushman, S., *Ibid.*, **25**, 1925 (338–360).
[9] Langmuir, I., *Ibid.*, **2**, 1913 (402–486).
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[11] Forsythe, W. E., and Worthing, A. G., *Astrophys. J.*, **61**, 1925 (146–185).

THE QUANTIZATION OF THE ROTATIONAL MOTION OF THE POLYATOMIC MOLECULE BY THE NEW WAVE MECHANICS

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In a recent article[1] in these PROCEEDINGS the writer has considered the quantization of the rotational motion of the polyatomic molecule by the classical quantum theory. Since that theory is being superseded by the new wave mechanics, it seemed to be of interest to treat the same problem by the new theory. As before, the polyatomic molecule is regarded as a rigid bodv with three principal moments of inertia, A_x, A_y, A_z, of which A_z is assumed to be the greatest or the least. The same coordinates are used as in paper number one, and in general when the same symbol occurs in both papers it represents the same quantity.

The kinetic energy T for the dynamical system under consideration, which is easily derived,[2] is

$$T = \frac{1}{2}\left\{\frac{[p_\theta \sin\theta\cos\phi + (p_\psi - p_\phi\cos\theta)\sin\phi]^2}{A_x\sin^2\theta} + \frac{[p_\theta\sin\theta\sin\phi - (p_\psi - p_\phi\cos\theta)\cos\phi]^2}{A_y\sin^2\theta} + \frac{p_\phi^2}{A_z}\right\}. \quad (1)$$

Here θ, ϕ, ψ are Euler's angles, and p_θ, p_ϕ, p_ψ are the conjugate momenta. Using (1) in the Schrödinger wave equation,[3] one obtains

$$(A + b\cos 2\phi)\,\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\,\frac{\partial U}{\partial\theta}\right)$$