at 17 years. The insensible perspiration for these girls per kilogram of body weight per hour was as follows: 0.72 gram at 13 years, 0.71 gram at 14 years, and 0.77 gram at 15 years. The respiratory quotients of groups of 12 girls each, about 7 to 8 hours after a light meal, were 0.81, 0.81, 0.78, and 0.79.

The basal heat production per kilogram of body weight per 24 hours decreases regularly with increasing age from 29.9 calories at 12 years 2 months to 21.7 calories at 17 years. The heat production per square meter of body surface per 24 hours likewise decreases, but not so regularly, with increasing age, ranging from 928 calories at 14 years to 745 calories at 16 years.

The metabolism of groups of young girls can be predicted from the general curve indicating the heat production per kilogram of body weight referred to age to within an average error of $\pm 3.1\%$. The prediction of the heat production per unit of body weight is somewhat better than that per unit of surface area. The curves representing the heat production per kilogram of body weight referred to weight and per square meter of body surface referred to weight for these groups of girls from 12 to 17 years of age blend with remarkable uniformity with similar curves based upon the measurement of a large number of normal girls from birth to 12 years of age.

No influence of puberty or the prepubescent stage is clearly proven in any of the results.

The details of the entire research are shortly to appear in the *Boston Medical and Surgical Journal.*

ON THE REFLECTION AND RE-EMISSION OF ELECTRONS FROM METAL SURFACES: AND A METHOD OF MEASURING THE IONIZING POTENTIAL OF SUCH SURFACES

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In making photo-electric measurements upon suspended droplets of mercury, one of us has repeatedly found that photo-electrons are always released when the droplet is illuminated by the ultraviolet line of wave-length 2536 Angstroms. On the other hand, it has been frequently proved that the molecules of mercury vapor are not ionized at all by these wave-lengths. The quantum of energy, then, which must be incident upon mercury in the liquid form in order to detach electrons from it is quite different from that required to detach electrons from the free atoms. It is to be expected from this fact that the "ionizing potential" also of liquid mercury will be quite different from that of the same element in the gaseous form. A considerable group of investigations has accordingly been begun in the Ryerson Laboratory for the purpose of determining, in the best vacua obtainable with modern means, the effect of surface conditions upon the emission of electrons from solids and liquids. Preliminary results from one of these investigations are reported herewith.

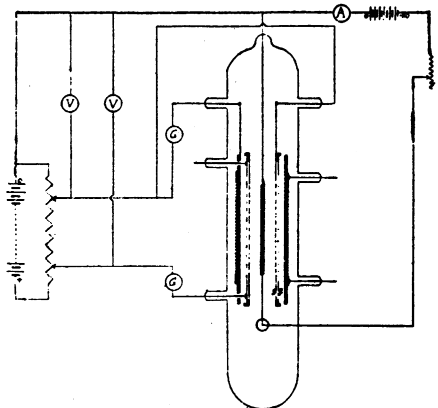

FIG. 1

The aims sought were:

1. To differentiate between the primary electrons which are reflected from a copper surface, and those which are emitted by such a surface because of the bombardment of the primaries.

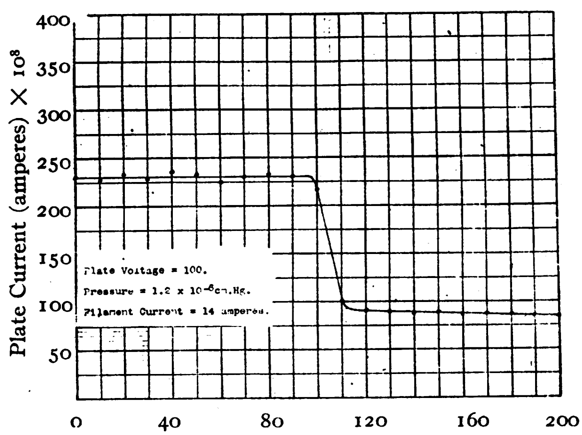

FIG. 2

2. To determine the exact potential at which the surface begins to re-emit under such bombardment. This will be called the ionizing potential of the surface.

3. To determine the number of electrons re-emitted per impinging electron as a function of the energy of impact.

4. To remove surface films by heat and to determine the effect of such films both upon the critical potential (2) and upon the amount of re-emission (3).

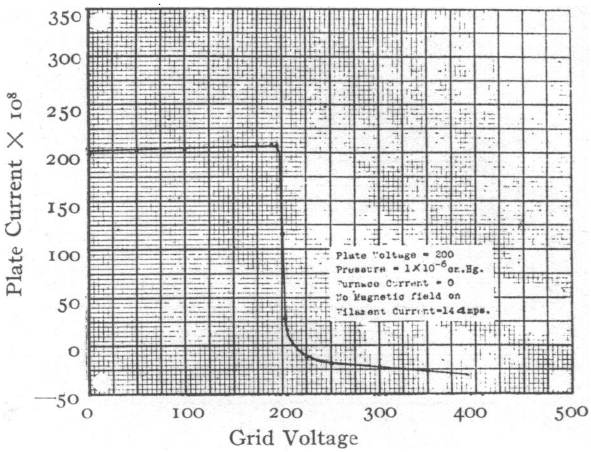

FIG. 3

5. To determine the effect of temperature alone upon the critical potential and the amount of re-emission after the surface had been well cleaned by the method of (4).

The apparatus designed in the endeavor to realize these aims and with which the following results have been obtained is shown, reduced to one-fourth natural size, in figure 1.

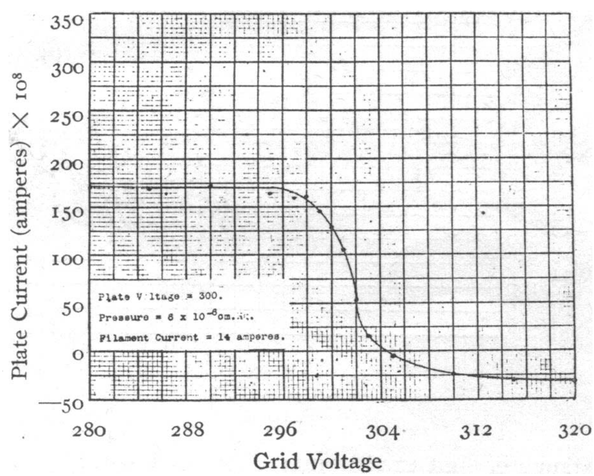

FIG. 4

The thermionic emittor consists of a central platinum cylinder 3 mm. in diameter, coated with the oxides of barium and calcium, and heated indirectly by a central tungsten wire (No. 22) from which it is separated by alundum cement. The emittor is thus *an equipotential surface.* Concentric with this emitting surface is a copper cylinder, *s*, 1.8 cm. in diameter, which will be called grid No. 1. About one-fiftieth part of its surface

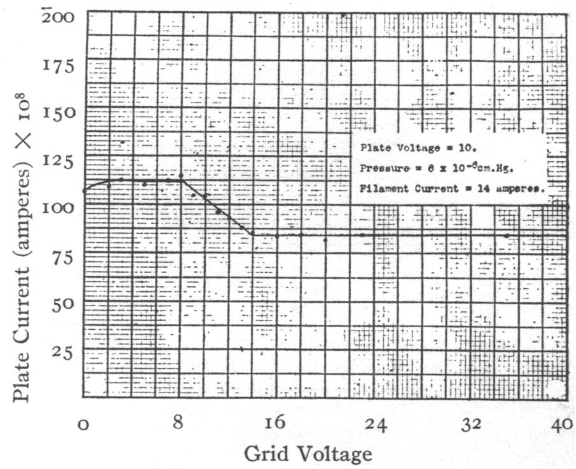

FIG. 5

is perforated with holes, uniformly placed, 1 mm. in diameter. Just outside this cylinder and insulated from it by quartz or porcelain rings 1 mm. thick is a second clyindrical grid, *g*, the holes of which are slightly larger

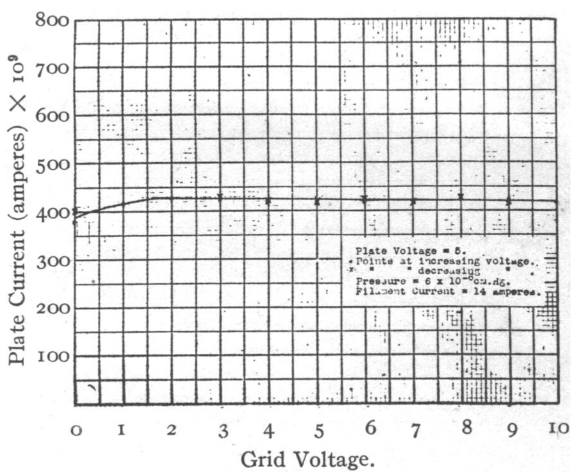

FIG. 6.

(3 mm. in diameter) but exactly match those of grid No. 1. Outside this is a third cylinder of copper, 3 cm. in diameter, which will be called the plate. The plate can be heated by means of a coil of nichrome wire wrapped about it but insulated from it with a soap-stone coating 2 mm. thick.

In the following observations the plate and grid No. 1 are kept at a common potential and both at a fixed potential, e. g., 100 volts, above the emittor. Figure 2 shows the curve obtained when the plate-current is plotted against the potential of grid No. 2 as the potential of the latter is varied from 0, the potential of the filament, up to 200 volts. When the potential of grid No. 2 has risen above that of grid No. 1, that is, above 100 volts, the secondary electrons, emitted by the plate under the bombardment of the primary electrons having an energy of 100 volts, are drawn from the plate to grid No. 2 and thus reduce the current flowing to the plate. Further, the difference between the two constant currents above and below the 100 volt value of abscissae is a measure of the secondary electrons which are attracted back from the plate. The ratio of this difference to the initial constant plate-current gives the number of secondary electrons produced at the plate per primary electron.

Again the difference between 100 volts and the potential at which the current begins to descend (see fig. 2) gives the maximum velocity of emission of secondaries in volts. Figures 3 and 4 show similar curves taken with primary electrons having energies of 200 and 300 volts, respectively, the latter being made with largely expanded abscissae so as to permit of a study of the distribution of velocities of the secondary electrons. It will be seen from figure 4 that practically no secondaries have a velocity of more than 5 volts, even when the exciting primary electrons have velocities of 300 volts. Further, figure 4 shows, since the potential reaches 310 volts before the current is again constant, that about 10 volts are required to pull out of the plate all of the secondaries generated. This is doubtless due to the fact that some of them are shielded by, or lost in, the pits and hollows in the surface of the plate.

Figures 5 and 6 show the curves obtained with primary electrons having energies of 10 and 5 volts, respectively. It will be seen that the maximum velocity of the secondaries obtainable from figure 5 is 2 volts. *The failure of the curve of figure 6 to drop at all as the potential of grid No. 2 passes through 5 volts seems to show conclusively that none of the 5 volt incident electrons are reflected, and also that the ionizing potential of the surface is above 5 volts; while figure 5 shows that it is below 10 volts.*

The accompanying table shows how the coefficient of secondary emission depends upon the energy of impact of the primary electrons in the case of a copper surface which had been subjected to red-hot temperatures for many hours. The coefficients were some 30% less before such treatment. On the other hand, increase in the temperature of the plate after treatment appeared to decrease the coefficient.

TABLE I

Impact voltage	5	7	10	15	20	25	50	75	100	150	200	250	300	400	500
Coef. of secondary emission	0	.08	.22	.30	.34	.40	.46	.58	.65	.86	1.00	1.10	1.26	1.25	1.25

The important results so far obtained from this work, which is still in progress, may be summarized as follows:

1. Contrary to current belief,[1] there appears to be no such phenomenon as the *direct reflection of* an electron from a copper surface, or if the phenomenon exists at all, the number so reflected at potentials less than the ionizing potential is negligible.

2. The result obtained in (1) reveals, therefore, a method of determining with simplicity and with considerable accuracy the ionizing potential of a metal surface. (The careful determination of the values of such potentials is now being carried out.)

3. As the energy of electronic impact increases, the amount of re-emission from copper increases up to about 300 volts, from which point on it remains essentially constant.

4. In the case of copper, the number of electrons detached per impinging electron is never found to exceed 1.3.

5. The number of secondaries per electron is somewhat increased by cleaning the surface by heat, and it appears to be somewhat decreased when the temperature of the surface is raised.

6. The maximum energy of emission of electrons released by electronic bombardment of copper increases from about 2 volts to about 5 volts as the energy of impact increases from 10 volts to 300 volts.

The full details of this work will be reported by one of us in a more extended article in the *Physical Review.*

[1] von Baeyer, O., *Verh. deut. physik. Ges., Berlin,* **10,** 1908 (903); also Gehrts, A., *Ann. Physik., Leipzig,* **36,** 1911 (996). Horton and Davies, *Proc. Roy. Soc.,* **97,** 23, 1920, obtained results which they interpret in terms of reflections, but which we do not think demand such interpretation. The article by Hull, A. W., *Proc. Inst. Radio Engineers,* Feb., 1918, should also be read, though it does not bear upon this particular point.

CHRONOLOGY OF THE SAN JUAN AREA

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Communicated by H. F. Osborn, December 2, 1920

The chronological outline herein presented is the result of ten years' research among prehistoric aboriginal remains in that portion of the San Juan watershed lying in northwestern New Mexico, southwestern Colorado, and adjacent areas in Arizona and Utah. In the earlier stages of the work, financial support was given successively by the School of American Archaeology, the St. Louis branch of the Archaeological Institute of America, and the University of Colorado. For the past five years the work has been under the direction of the American Museum of Natural History as a part of the Archer M. Huntington Survey of the Southwest.