THE MERCURY-ARC PUMP; THE DEPENDENCE OF ITS RATE OF EXHAUSTION ON CURRENT.

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SINCE the diffusion pump of Gaede[1] was described a number of investigators have produced modifications all operating on the same principle, the latest that of Knipp.[2] The pump here described differs only in the manner of driving and in introducing and taking off the mercury. This permits using the pump as a mercury still at the same time that it is being used for exhaustion purposes.

Fig. 1 is a reproduction of the pump in its most desirable form. Two barometer columns introduce the mercury to the arc, the arc being started by blowing in the one neck of the Woulff bottle as shown at *B*.

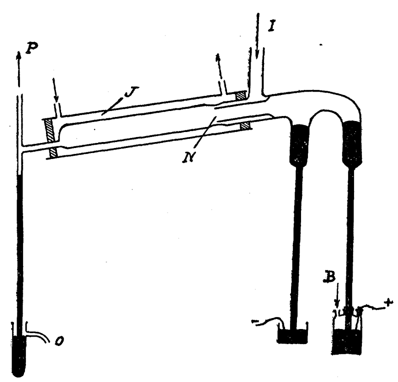

Fig. 1.

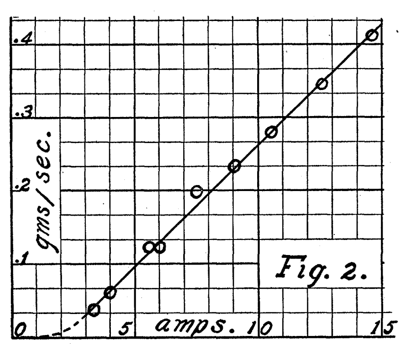

Fig. 2.

The mercury vapor is driven through the nozzle, *N*, and condenses in the chamber surrounded by the water jacket, *J*. The condensed clean mercury is then drawn off at *O*. The water jacket is conveniently made of metal and the ends made watertight by rubber stoppers. Danger of breakage, when made of ordinary glass, was encountered only at the higher current values, 15–30 amps., which heat the arc quite above the temperature necessary for highest efficiency. With the pump constructed of Pyrex glass no difficulty is experienced due to breakage.

[1] Ann. d. Phys., 46, p. 357, 1915.
[2] PHYS. REV., N.S., IX., p. 311, 1917.

The supporting punp was a Gaede rotary mercury pump connected to P. The vessel to be exhausted was connected through a liquid mercury stopcock to the intake, I. Fig. 2 shows the relation between the driving current and the rate of flow of the mercury vapor through the nozzle. Each point represents a value deduced from a one-hour run at that current value. The curve is evidently a straight line for values above 3 amps. The dotted line gives the most probable form of the curve for lower values.

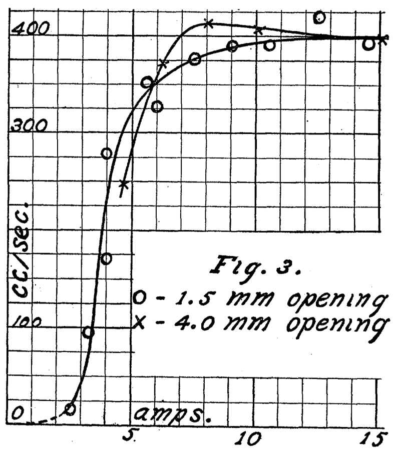

Fig. 3.

The pump was connected through about 200 cm. of 2 cm. tubing (liquid mercury valve but no vapor trap) to a 6.5 liter vessel. The pressures were measured by means of a 500 c.c. McLeod gage and the rate of exhaustion was determined by pumping always between pressures for which the McLeod gage is reliable. The annular space about the nozzle, N (Fig. 1,) was first made of 1.5 mm. width. The one curve of Fig. 3 shows the rate of exhaustion for this annular opening as calculated by Gaede's formula[1]

$$S = \frac{V}{t} \log_e \frac{p_1}{p_2},$$

where p_1 and p_2 are the pressures before and after exhausting the volume V for t seconds. The speed, S, is in c.c. per sec.

To determine the reason for the maximum rate of exhaustion the water jacket was removed and the annular opening blown out to 4 mm. width. Fig. 3 shows that the rate of exhaustion was not markedly altered. The limiting rate of 400 c.c. per sec. is due to the quite long length of 2 cm. intake tubing. If this tube were short enough and large enough the curve would most likely be a straight line after passing the 3.5 amp. value until the limiting value due to the size of the annular opening is reached. This suggested that if the pump be allowed to operate without reducing the pressure, as in pumping against a leak, a definite number of mercury molecules are required to remove a single air molecule.

Fig. 4 shows the relation between the number of mercury molecules per air molecule and the pressure (average of p_1 and p_2) in cm. The

[1] Loc. cit.

curve is plotted for the current value 6.15 amps. Curves were plotted for other current values and found to be not essentially different. Table I. gives the data from which the curve is plotted.

The curve is not unexpectedly asymptotic to the vertical axis since

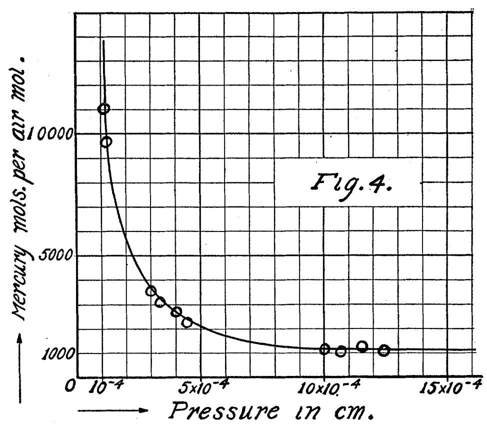

Fig. 4.

mercury vapor flows through whether air remains to be exhausted or not. The fact that at the higher pressures only 1,000 mercury molecules are

TABLE I.

Time of Pumping, Sec.	p_1 Cm.	p_2 Cm.	Speed of Exhaustion Cc. per Sec.	Molecules of Air per Sec.	Molecules of Mercury per Air Molecule.
20.7	.00166	.00064	300	2.50×10^{17}	1,220
21.2	.00064	.00017	413	1.15 "	2,650
21.0	.00017	.00005	357	.28 "	11,100
20.0	.00178	.00069	306	2.80 "	1,090
20.4	.00069	.00018	443	1.29 "	2,360
20.4	.00018	.00006	380	.31 "	9,700
20.2	.00152	.00047	376	2.67 "	1,140
20.3	.00047	.00013	370	.86 "	3,540
20.0	.00163	.00052	370	2.85 "	1,070
19.8	.00052	.00014	425	.98 "	3,130

required to direct the motion of an air molecule is particularly interesting. It remains to be seen whether this unexpectedly small indicated value holds for pressures as high as atmospheric. The straightness of the path of an alpha particle passing through saturated air at atmospheric pressure, as is so nicely shown by C. T. R. Wilson's[1] well-known photographs, is interpreted as intermolecular penetration. The relative velocity of the

[1] Phil. Trans. Roy. Soc., A, 189, p. 265; 192, p. 403; 193, p. 289.

mercury and air molecules is quite small compared with that of an alpha particle and the time they are within a given distance of each other is correspondingly long. Whether this fact is sufficient to account for the small number of mercury molecules required to direct an air molecule or whether there is an essential difference between the mercury and helium atoms cannot at present be told. The authors had hoped to continue the work by several obvious experiments but other duties will surely prevent it.

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