considerable telluric acid had been reduced but that the decomposition was not complete. An experiment extending over three days brought about complete reduction of the telluric acid.

Reduction by Selenium.—When selenium and 30% telluric acid are allowed to react at 110° selenious acid and tellurous acid are formed. The reaction is incomplete at the end of eighteen hours, but after two and one-half days there is no telluric acid left in the solution, showing that the reduction is complete.

Conclusion.

Telluric acid in aqueous solution of any concentration is reduced by hydrogen sulfide and sulfur dioxide slowly. Tellurium, sulfur, and selenium also reduce solutions of telluric acid.

The difficulty of reduction is not what would be expected from a knowledge of the gradation of oxidizing properties in the two lower members of the family in which tellurium is placed; in fact one would expect telluric acid to be even more readily reduced than selenic acid. Thomsen's thermochemical data, however, show that the oxygen compounds of selenium should be reduced more easily than those of sulfur or tellurium. This has been found to be true.

The author takes pleasure in acknowledging his obligation to Victor Lenher, who suggested the subjects of this and the preceding paper, and under whose inspiring direction the investigations were conducted.

MADISON, WISCONSIN.

MERCURY VAPOR PUMPS FOR OPERATING AGAINST HIGH PRESSURES.

By CHARLES A. KRAUS.

Mercury Vapor Pumps, as originally designed by Gaede,[1] and subsequently modified by Langmuir,[2] have proved invaluable in many instances for laboratory operations. These pumps, however, have been designed primarily with a view to speed of operation and as such have usually required the use of a supporting pump giving a relatively high vacuum. For many laboratory operations the speed is often of necessity determined by other conditions, such as the dimensions of connecting tubes, etc. It seemed worth while, therefore, to design a pump which should obviate the necessity of a mechanical supporting pump.

A good water-jet pump will give a vacuum ranging from 8 to 25 mm. depending on the temperature. It was, therefore, undertaken to design a pump which could be supported by a water-jet pump. It was not found
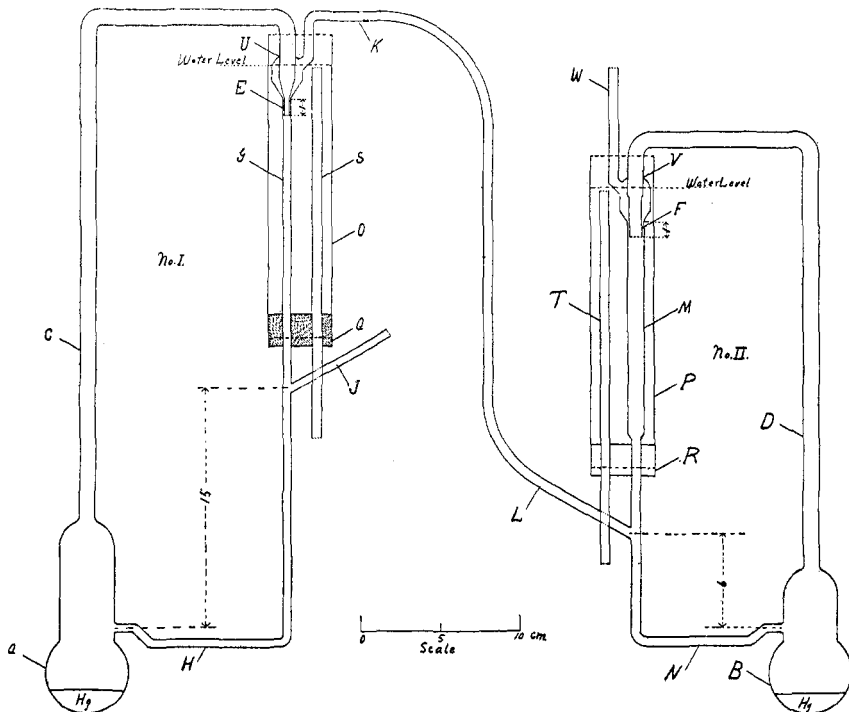
[1] *Ann. Phys.*, [4] 46, 357 (1915).
[2] *Phys. Rev.*, [2] 8, 48 (1916); *J. Franklin Inst.*, 182, 719 (1916).

practical, however, to construct a high vacuum pump operating against a back pressure of more than 7 to 8 mm. Two pumps were therefore constructed, operating in series and supported by the water-jet pump.

It is obvious that in designing these pumps it is necessary to give the mercury vapor at end of the nozzle a velocity sufficiently high to overcome the difference in pressure between the apparatus to be exhausted and the supporting vacuum. In order to avoid using large amounts of mercury, the nozzle must be constructed sufficiently small to give the necessary velocity. In the two pumps described below, the supporting pump No. I operates against a back pressure as high as 40 mm. and yields a vacuum below 1 mm.

The high vacuum pump No. II operates against back pressures as high as 7 or 8 mm. and produces a vacuum as high as is attainable by pumps of this type. The nozzle in this case is much larger than in the first pump and a smaller volume of mercury vapor suffices to carry on the process of evacuation. The dimensions and arrangements of the pumps are shown in the accompanying figure, drawn to scale. The boiling chambers A B have a diameter of about 5.6 cm. The tubes C D leading to the nozzles E F have a diameter of about 1 cm. In pump No. I, the nozzle has an internal diameter of approximately 3 mm. and projects through the con-

densing chamber G a distance of 1 cm.   A space of 0.5 mm. is allowed
between the exterior surface of the nozzle and the interior surface of the
condensing chamber.   From the condensing chamber the mercury falls
into the trap H from which it flows back into a reservoir, A.   The water
jet pump is attached to the supporting pump through the tube J.   A
distance of 15 cm. is allowed between the point at which the tube J is
joined to the condensing chamber G and the point at which the mercury
flows into the reservoir A.   This is essential, since, in order to obtain
the necessary velocity of mercury vapor in the nozzle, pressure is pro-
duced in the boiling chamber A which backs the mercury up in the other
arm of the trap.

The tube K is connected to the tube L of pump No. II either by means
of a glass tube or by means of a heavy walled rubber tube.   The construc-
tion of pump No. II is similar to that of No. I except that the nozzle F
and the condensing chamber M are larger.   The diameter of the nozzle
F is approximately 8 mm. and projects 1 cm. into the condensing chamber.
The annular space between the exterior surface of the nozzle and the in-
terior surface of the condensing chamber is 0.5 mm.   This space can be
made larger if desired, but if this is done the pump will not operate against
so high a back pressure.   The tube L is joined to the pump at a point 6
cm. above the outlet of the trap N.   The tubes C and D of the two pumps
are preferably wrapped with asbestos cord to prevent loss of heat.   The
boiling chamber of pump No. I should be supplied with a liberal amount
of mercury, somewhat as indicated in the figure, and the flame is adjusted
so that the mercury boils vigorously, giving a pressure of about 10 cm.
of mercury, as indicated on the one arm of the trap.   It should be noted
that any given pumps operate best at a certain pressure of mercury vapor.
For the pump No. I, as described above, this pressure is about 10 cm.,
but its exact value cannot readily be determined except by experiment.
Once it has been determined, it is best to mark the position of the meniscus
on the long arm of the trap and thereafter the flame is adjusted so as to
yield this pressure.   In the case of pump No. II, a smaller amount of
mercury may be introduced in the boiling chamber B.   The flame in the
case of this pump is adjusted so that the mercury barely boils, and the
pressure of mercury vapor, as indicated in the long arm M of the trap,
is only about 2 cm.   It is particularly necessary that the pressure be not
raised too high on the pump No. II.   The condensing chambers G M are
surrounded by water jackets O P which consist of cylindrical glass tubes
provided with rubber stoppers Q R at the bottom.   The level of the
water is controlled by the over-flow tubes S T which are so adjusted that
the water level is about 5 mm. below the seals U V, as shown in the figure.
The apparatus is attached to No. II pump through the tube M.   Water
is introduced at the bottom of the water jackets by means of glass tubes

not shown in the figure. If desired the water jackets may be blown on to the pump, but in practice I find it preferable to attach the water jackets by means of rubber stoppers as described. The pumps may be constructed of any glass resistant to temperature change. The use of ordinary soda glass or lead glass is not to be recommended. Pyrex glass may be employed but I have found that another glass[1] works much more readily than pyrex glass while at the same time it has as low a coefficient of expansion. This glass reduces slightly in the ordinary blow-pipe flame and is somewhat less fusible than ordinary soda glass and requires a larger supply of air. Simple glass blowing operations can be carried out in an ordinary blow-pipe flame. If it is desired to avoid reduction or to carry out more difficult operations in glass blowing, it is preferable to employ oxygen in finishing the operation.

Any good water-jet pump is satisfactory as supporting pump. In practice I have found it convenient to construct my own pump using G-702-P glass for the purpose. The effectiveness of the water-jet pump depends largely on the relative diameter of the nozzle and the delivery tube. A nozzle having an interior diameter of 2 mm. and a delivery tube having an interior diameter of 5 or 6 mm. will give a pump which operates very well, and, if necessary, it is easy to construct a pump which operates at a pressure below 40 pounds. The delivery tube should be simply a straight tube about 20 to 25 cm. long. It is essential that the delivery tube and the nozzle be carefully lined up, as the pump will not operate properly if the jet strikes the side of the delivery tube. A bottle should be introduced between the water-jet pump and No. I supporting pump and it is also convenient to introduce a manometer. To start the pumping operation, the apparatus to be exhausted is joined to tube W by means of a ground joint or by cement. The water-jet pump is then put in operation and when the pressure has fallen to about 25 mm., the burners are lighted. If these burners have been previously adjusted, the pump requires no further attention. The pump will begin to operate within several minutes after lighting the burner. I have been able to exhaust a volume of about 1500 cc. to less than 10^{-4} mm. of mercury in about 10 minutes.

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NOTE.

An Improved Hydrogen Chloride Generator.—Of the numerous methods employed to generate hydrogen chloride for lecture table experiments, and for investigations, none are entirely satisfactory, the chief objection to most of them being that the quantity of gas evolved cannot easily be controlled, or is not uniform. A careful quantitative study of all

[1] Manufactured by the Corning Glass Works of Corning, N. Y., G-702-P'.