[Contribution from the Laboratory of Plant Physiology, Harvard University.]

AN IMPROVED QUARTZ MERCURY-VAPOR LAMP FOR BIOLOGICAL AND PHOTOCHEMICAL INVESTIGATIONS.

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Received April 29, 1915.

In a former paper[1] the writer described a simple quartz mercury-vapor lamp for photochemical investigations. In the present paper a much more powerful lamp is described. The improved lamp is so simple, efficient and durable that the employment of ultraviolet light in biological and chemical investigations should be decidedly facilitated by its use.

The principles of the mercury air-pump have been incorporated into the design so that no pump, other than an ordinary water aspirator, is required to exhaust the lamp to a very high vacuum. This feature not only does away with all troubles connected with the original exhaustion of the lamp, but makes it possible to re-exhaust the lamp quickly and easily at any time. The lamp can be re-exhausted without in any way disturbing the chemical substances under investigation and without interrupting the exposure for more than a fraction of a minute. The length of life of the lamp is, therefore, limited only by the durability of the quartz. A maximum of efficiency is obtained by constructing the apparatus so that the exposed substance receives practically all of the light given out. The temperature of the substance which is being investigated is at all times under the control of the operator.

The lamp consists of a transparent quartz tube, 70 cm. in length, closed at one end with a stopper of invar and inverted in a cistern containing pure mercury. The mercury cistern (*A*), Fig. 1, is closed at the top by a rubber stopper *B* through which the quartz tube passes. The air pressure in the cistern *A* may be varied by admitting or removing air through the side tube *C*. The height of the mercury column *D* varies with the air pressure in *A*. The quartz tube is of 7 mm. internal diameter, for the greater part of its length. It is enlarged at *E* to form an air-trap, also at *F* to form a condensation chamber, and again at *J* to form a reservoir for a mercury seal. The construction of the air-trap *E* will be understood from the drawing. Immediately above the air-trap is a water-jacket, *O*. Water circulating through this jacket serves to keep the positive electrode cool. This makes it possible to greatly increase the current density of the arc. The condensation-chamber *F* has at its lower end an internal flange which, together with the wall of the chamber, forms a pocket to hold a ring of mercury *G* which forms the negative electrode of the lamp. The wall of the tube is thickened at *H* and is ground to receive the conical end of the invar stopper *I*. This ground joint is sealed with mercury at *J*. The top of the quartz tube at *K* is constructed so as to fit closely about

[1] *J. Biochem.*, **20**, 315 (1915).

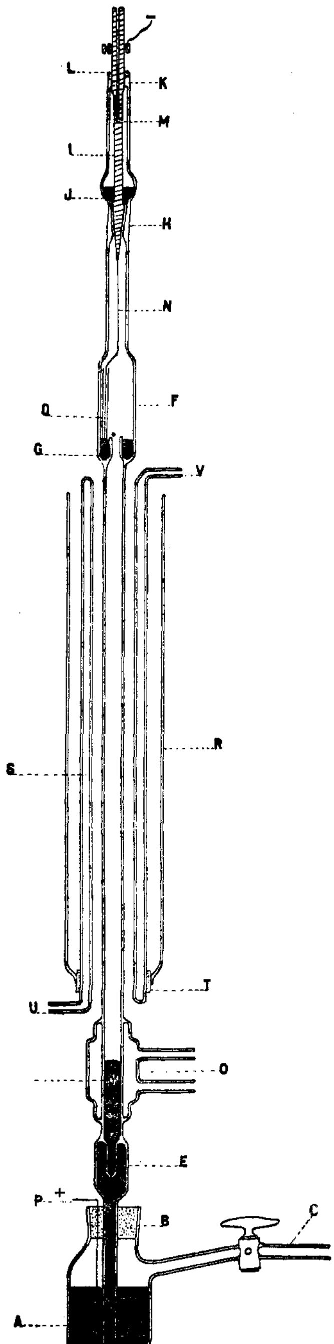

Fig. 1.

the upper part of the invar stopper. The joint here is made practically air-tight by a ring of soft, rubber gum, L. This construction of the joint at K makes it possible to slightly raise or lower the invar stopper without destroying the seal at J. A small hole extends along the axis of the upper part of the invar stopper and opens at M into the space between the joint K and the mercury seal J.

The invar stopper has electrical connections with the mercury ring G by the soft iron wire N. It is essential that the lower end of the iron wire N terminate in a ring which dips well beneath the surface of the mercury. Otherwise when heavy currents are passed through the lamp and the mercury ring G contracts, due to the so-called "pinch-phenomenon," the end of the iron wire will be exposed and will be melted off because of the intense heat of the arc which will thus be formed between it and the mercury ring G. The lower part of the wire is further protected by a small quartz tube, Q, the lower end of which dips beneath the surface of the mercury. Without the protection of the quartz tube Q the wire itself, instead of the mercury ring G, will become the negative electrode and the heat thus developed will cause the wire to melt.

The condensation chamber F is cooled by a copper radiator or better by an air-blast.

The upper surface of the mercury column D serves as the positive electrode of the lamp. The current is conducted to it through the iron wire P which passes out through the rubber stopper B.

The lamp is evacuated as follows: The top of the invar stopper is connected by means of a rubber tube to the water aspirator. The stopper is lifted slightly so as to leave an opening at the ground joint H and the aspirator is started. The air is thus drawn out from the body of the tube. The stopcock *C* is opened and as the quartz tube is evacuated, the mercury column *D* rises. The pumping is continued until the mercury column reaches and passes the ground joint at *H*. The stopper is then pressed down so that the joint is closed. The mercury which has passed above the joint serves as an air-tight seal.

The tube *C* is now connected with an aspirator and the air pressure in the cistern is reduced. The mercury column falls, leaving a Torricellian vacuum in the space below the invar stopper. In order to remove the last traces of air from the lamp it is necessary to boil the mercury column *D* during the first pumping, and in order to insure an air-tight seal at *H* the mercury in *J* must be boiled each time the seal is made. The occluded gases which are usually contained in the iron wire *N* and which are driven out during the first few "burning hours" of a new lamp, are removed from time to time by allowing the mercury column *D* to rise past the joint *H*. After these gases have been removed, the lamp seldom needs to be repumped. After pumping, the aspirator is disconnected from the invar stopper *I*, leaving the space above the mercury at *J* open to the outside air.

The invar stopper should not be heated while it is seated in the grinding at *H*. There is sufficient expansion of the invar at high temperatures to break the quartz. As long as the partial vacuum is maintained in the space above *J*, the stopper may be held up out of its seat without losing the mercury seal. The stopper is seated only when the lamp has cooled. It will be understood that the Bunsen flame may be turned directly on the quartz without fear of breaking. After heating the lamp is cooled immediately by a dash of cold water.

The lamp is operated on a direct current in series with a resistance, which, for voltages above 110, should be variable. It carries a current of from 12 to 15 amperes. The maximum length of arc obtainable is dependent upon the voltage of the line upon which the lamp is operated. With 110 volts on the line, an arc of about 9 inches can be maintained. With 220 volts, the lamp burns with an arc over 2 feet long. It is essential that the mercury column *D* be made the positive electrode; the lamp will not burn if the poles are reversed.

The solutions to be exposed to the light are contained in the triple-walled beaker *R*. The outside wall of the beaker is made of glass. The inside *S* is a screen for absorbing the heat rays. It is a double-walled quartz tube with the space between the walls open to the outside through the small tubes *U* and *V*. The heat rays are absorbed by a stream of water which passes between the walls of the tube. By adding various substances to the water, the double-walled quartz tube may be used as a selective light filter, or if desired, it may be used as a chamber in which to expose gases. The outside wall of the beaker is joined at *T* to the inner part by a rubber ring which forms the bottom of the beaker. Rubber is very unstable under the action of ultraviolet light, and it would be better to have a ground joint at *T*, but the quartz tube used by the writer is too thin to stand grinding. The beaker has a capacity of 100 cc.

For measuring the temperature and stirring the solution during the exposure, a device is employed which is not shown in the drawing. It consists of a hollow gold wire (size No. 14 Brown and Sharp gage), bearing two rings of gold which encircle the inside wall of the beaker. The device is given a slow up-and-down motion by a crank on a driving motor. The upright hollow gold wire extends above the beaker and is open at the top, so as to receive one of a pair of thermal junctions made up of No. 32 "Ideal" and copper wires. The other (constant) junction is placed in water in a Dewar flask which is provided with a thermometer. The variable junction is pushed well down inside the hollow gold wire. The free ends of the copper wires are connected with a galvanometer which is sufficiently sensitive so that differences in the temperatures of the two junctions can be read to 0.1°.

The lamp is operated as follows: The line wire is disconnected from the invar stopper *I*. The beaker *R* is slipped off over the top of the lamp, and, if necessary, its outer and inner parts are separated at the joint *T*, so that the surface of the inner part *S* can be cleaned. The beaker and line wire are now replaced. The variable resistance is set so that when the lamp is short-circuited it will carry between one and two amperes. The stream of water is now started through the water-jacket *O*. Air is admitted into the cistern *A*, causing the mercury column *D* to rise until electrical contact is made with the electrode *G*. The air pressure in the cistern *A* is now reduced, and the mercury column falls, stretching out the arc between *D* and *G*. The variable resistance is now adjusted so that the lamp carries the desired number of amperes. The current may be varied from less than one ampere to the full carrying capacity of the lamp.

Connections are now made at *U* and *V*, water is allowed to flow through the space between the walls of the tube *S*, and the solutions to be exposed are placed in the beaker.

Fig. 2 is from a photograph of the lamp as installed in the Biophysical Laboratory of the Cancer Commission of the Harvard Medical School. The lamp is inclosed in a metal case made from a brass tube 6 inches in diameter. It passes through a hole in the table (the mercury cistern *A*, Fig. 1, resting on the shelf below) and is held in an upright position by a light framework which is attached to the case near the top. The brass tube, forming the case, is split longitudinally into halves which are hinged together along one side. One-half only is fixed to the table, the other movable half forming a door. The tube can thus be opened, making all parts of the lamp readily accessible.

As installed in this laboratory the lamp case is provided with a flue which passes up into the ventilator of the chemical hood. This flue is not necessary when the lamp is used in connection with the beaker described

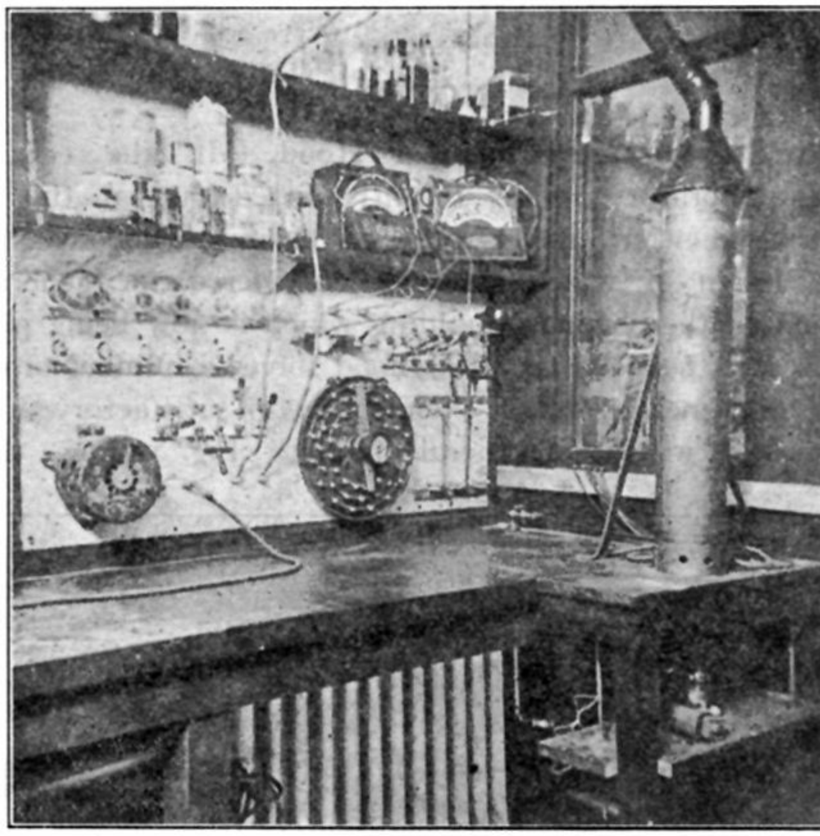

Fig. 2.

above. When used without the beaker, however, the ozone produced makes the laboratory a very unpleasant place in which to work, unless some means are provided for carrying the exposed air out of the room. The flue also disposes of a great deal of heat.

It is difficult to give an accurate description of the intensity of the light produced. Judging from the current density the light is much more intense than that produced by any lamp which has been previously described. Perhaps the following statement will serve to give an idea of the efficiency of the lamp in producing ultraviolet rays: It is known that egg-white is slowly coagulated by ultraviolet rays. In order to test the lamp, egg-white was diluted with water to make a 2% solution. The solution was brought to its isoelectric point and filtered clear; 100 cc. of the filtrate were placed in the beaker of the lamp, and the stream of water passing through the water-jacket was adjusted so that the solution of egg-white had a temperature of 16°. A flocculent coagulum began to appear 4 min. after the lamp was lighted. In this experiment the lamp was carrying a current of 11 amperes. (The amount of light probably varies as the square of the current density.)

It will readily be seen that the lamp is simple to operate and of great efficiency. It is hoped that it will prove to be of value in extending the use of ultraviolet light in biological and photochemical investigations.

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NOTES.

A Simple Stone-frame Chemical Hood.[1]—In the equipment of three of the laboratory rooms recently fitted out at the Bureau of Standards, a somewhat novel type of chemical hood has been installed, the design of which is being considered for general use in the equipment of the chemical building which is now being planned for the Bureau. It is believed that this hood solves a number of difficulties which have been met by other chemists in so satisfactory a way that a description of it will be of general interest. Fig. 1 shows the general

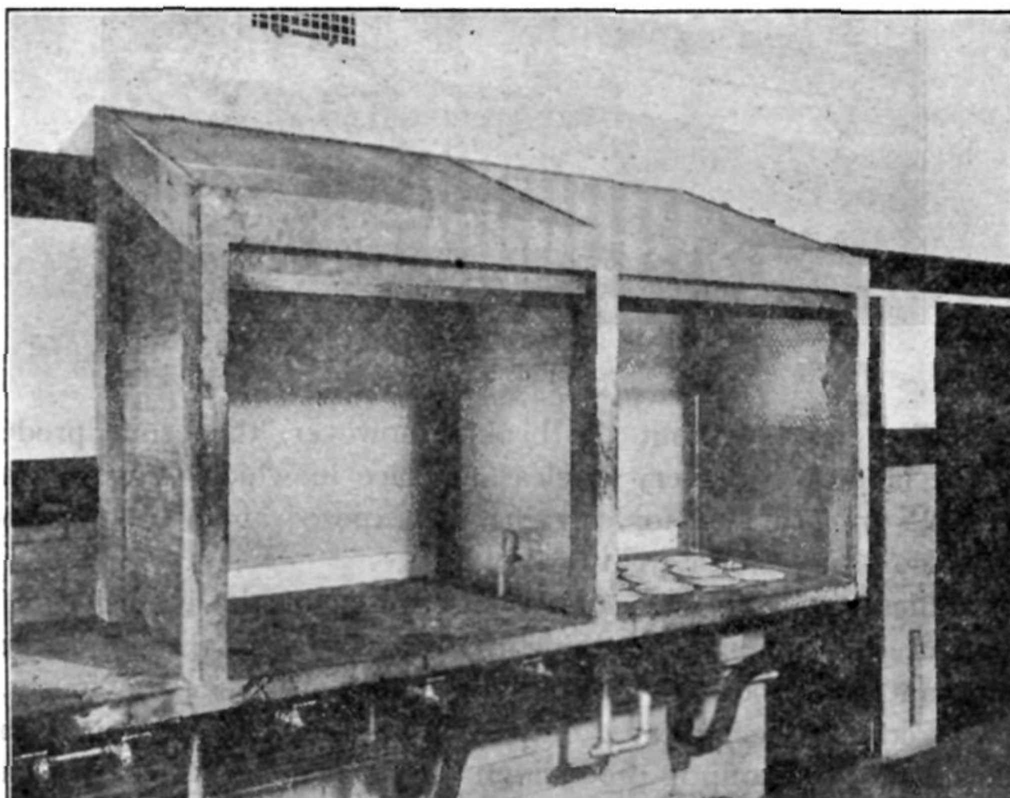

Fig. 1.

character of the simpler form of hood which has been used. This hood has the following advantages:

(1) It is simple, neat in appearance, of light weight, well lighted and, for a stone-frame hood, comparatively inexpensive.

(2) The inside of the hood, except the floor, is almost entirely of glass. There is no wood or metal at any point within the hood nor are there

[1] Published by permission of the Director of the Bureau of Standards.