WATER-COOLED LAMP SYSTEMS WITH REFLUXING AQUEOUS FILTERS[1]

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Received August 22, 1952

When plants are grown under high irradiances of incandescent lamp radiation, temperature control becomes difficult unless the infrared is removed. The infrared energy radiated by standard incandescent lamps is from 75 to 85% of the input power (**2**). Excessive heating of exposed portions of the plant results from direct absorption of infrared energy since most of that energy is in the region of the water absorption bands.

The most effective filters for removing the near infrared are water or solutions of the ferrous or cupric salts (**3, 4, 5**). If the filters consist of shallow tanks open to the air, the rapid loss of water due to evaporation necessitates constant maintenance. Since most of the radiated energy is absorbed in the top layer of water, the temperature gradient does not induce appreciable convection. While cooling coils placed in the body of the liquid may keep the bottom of the tank cool, they do not appreciably reduce the evaporation rate.

In attempting to solve the problem of evaporation in unsealed systems, it was found that if the water-cooling coils were suspended in the air space above the water surface, the water vapor was condensed on the coils and refluxed back into the tank. In addition, the cold condensate dropping upon the water surface set up convection currents, further reducing the temperature and evaporation. If the coils are placed near the top of the unit around the lamps, the air temperature is kept within safe limits for a completely enclosed but not sealed system.

Two types of lamp unit which have been constructed and used extensively in our laboratories are shown in detail in figures 1 and 2. Both of these units are designed for use with a layer of water or solution and the standard line of internal reflector lamps. A 10-cm. layer of water, as used in the large lamp unit of figure 2, absorbs all infrared beyond ca. 1150 mμ (**1**). The addition of 30% ferrous ammonium sulphate decreases the limit to ca. 760 mμ and copper sulphate can be used to remove both red and infrared beyond ca. 600 mμ. The 75-watt incandescent internal reflector lamp is four inches in diameter, and the 150- and 300-watt incandescent and the 100-watt mercury arc lamps are five inches. The incandescent lamps are available as reflector flood or spot lamps. The spot lamp is especially useful for very high irradiances over a small area; the flood is better for irradiation of larger areas.

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In the construction of these lamp units, special consideration must be given to the selection of water-resistant and thermally stable materials. The lamp holders or sockets must be all porcelain. Porcelain sockets with plastic center insulation will eventually arc and fail. The top mounting plates should be of a water-resistant, resin-impregnated asbestos board such as is used for electrical insulation or chemical bench tops (Chemstone). Unimpregnated asbestos Portland cement panels may be used if properly treated with a heat-resistant enamel, preferably of the baking type.

The small unit of figure 1 has proved very useful for the general irradiation of single large plants or small cultures of seedlings or algae. It can be mounted on small cabinets in combination with gelatin or glass filters where narrow spectral regions are required. The glass vessel may be either a 4000-ml. standard beaker or a molded Pyrex cylinder six inches in diameter

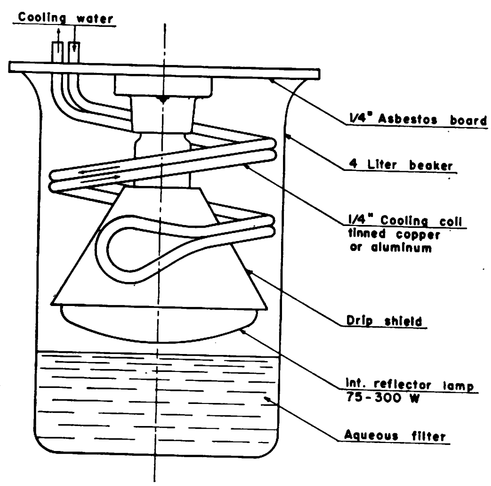

FIG. 1. Single water-cooled refluxing lamp unit.

and 12 inches high. Eight linear feet of tubing with an outside diameter of one fourth of an inch when wound into a double spiral is adequate for a 300-watt lamp when the cooling water runs below 20° C. Since copper tubing becomes oxidized with continued operation, it is desirable to use either tinned copper or aluminum. The coil can be made readily by bending the eight-foot length of tubing in the middle, after first annealing a foot of the center section to prevent collapse on bending. The two legs then can be soldered at various points along the length and coiled on a mandrel. The upper part of the coil should be supported by tying with copper wire or soldering to a pair of long machine screws bolted into the top (not shown in diagram).

The outdoor type of internal reflector lamp of hard glass will withstand contact with cold water without breaking, but these lamps are more expensive than the indoor type. The indoor type may be used if a drip shield of aluminum or copper is employed. These shields consist merely of a truncated cone as shown in figure 1. Aluminum or copper foil wrapped about the upper part of the lamp will serve the same purpose.

A 300-watt lamp unit will deliver ca. 1200 fc at 12 inches; the radiant flux distribution is more uniform if the lamp system is used within a white enclosure. Using a beaker with a lip open to the atmosphere, the unit can be operated with a 300-watt lamp continuously for a period of several weeks with very little water loss. Without the cooling coil, such a system requires the addition of water several times daily.

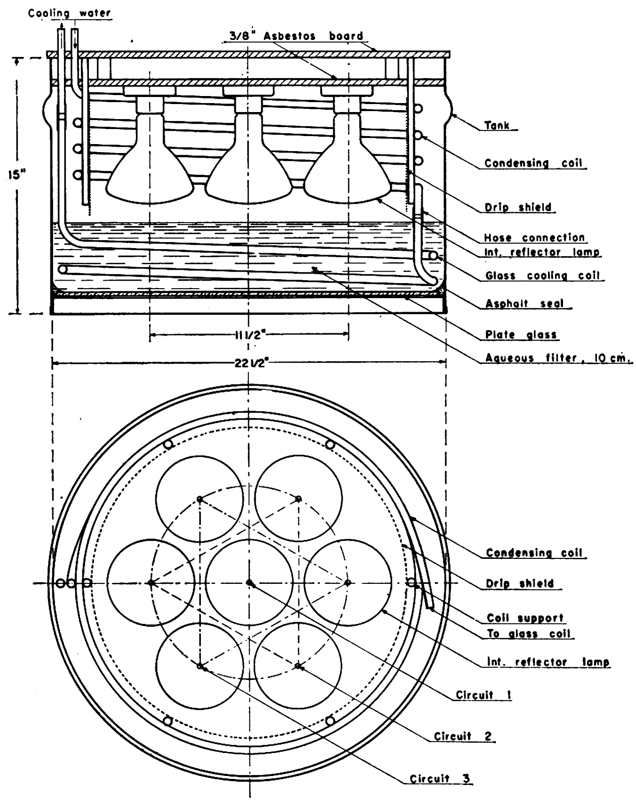

FIG. 2. Multiple water-cooled refluxing lamp unit.

The multiple lamp unit (fig. 2) is designed to operate with a maximum power input of 2100 watts (seven 300-watt lamps). A cooling coil made of 25 feet of copper or aluminum tubing of an outer diameter of three eighths of an inch usually will keep all parts of the system cool, but 50 feet has been found more satisfactory when maximum power is used. Seven lamp holders are mounted as shown, six in a ring and one in the center. Three of the six in the ring are alternately wired to one outlet connector, the other three to a second, and the center lamp to a third, thus making it possible to operate the unit with one to seven lamps as desired. When three or fewer lamps are required for an experiment, six lamps can be installed, making it possible to switch to an alternate set in case of lamp failure. The cover supporting the lamp holders consists of two panels, one lower centering panel within the tank, separated from the top panel by spacers. All the wiring is confined to the space between the two panels.

It was found that occasionally lamps broke because of water dripping from the upper coils onto the water surface, causing splashing upon the bottom face of the bulb. This was completely eliminated when copper screen wire was mounted as a cylinder on the inside of the coils. Solid sheet material could not be used since it interfered with air circulation.

In experimental work where precise air temperature control is required, it also is necessary to cool the aqueous filter layer directly. Where water alone is used, copper or aluminum tubing is quite satisfactory, but filters such as acidulated copper sulphate solutions attack all the common metals as copper, brass, aluminum, tin, and lead, and it is necessary to use tubing of stainless steel, silver, or glass. Rubber and plastic tubing do not have sufficient thermal conductance to be effective unless very large surfaces are employed. The coils may be held to the upper assembly by copper wire covered with vinyl plastic electrical sleeving.

The tanks can be constructed from standard 50-gallon alcohol drums; two tanks can be obtained from each drum. A 15-inch section is cut from either end of the drum, forming the two tanks. The bottom of each tank is then cut out so as to leave a one-inch flange to hold a glass bottom. The cutting of the drums is effected readily by a high-speed power-driven hack-saw mounted in a portable electric drill.

Where only water is used as the filter, vinyl synthetic resin air-drying finishes such as Tygon are fairly satisfactory for coating the inside of the tanks. However, all air-drying finishes which we have used failed in time and this failure was greatly accelerated by acidulated solutions. The only finish found satisfactory for such use is the baking-type of polymerizing vinyl resin such as used for coating industrial electroplating pickling tanks. One such finish which has proved especially satisfactory is white Miccrosol (E-1266, Michigan Chrome and Chemical Company). The primer is brushed on and baked for 15 minutes at 180° C; then the adhesive brushed on and baked in a similar fashion. The final coats of Miccrosol are applied as two or three layers by brushing, each coat given a short bake of 15 minutes at 180° C to just set the material. After all the coats have been applied, the tank is given a final bake at 180° C for two hours. The final finish is tough and rubbery and appears to be resistant to strong acids and alkalis and will withstand high temperatures.

The glass bottom is sealed into place with a high-melting air-blown asphalt compound similar to the type used for sealing storage batteries. Rubberseal no. 3 (Mitchel Rand Insulation Company) is very suitable and does not harden with age. It is applied by pouring a fillet of the hot asphalt on the bottom tank flange. The warmed glass is then gently lowered onto the asphalt and the whole assembly placed in an oven at 100° C until a complete seal is effected. Aquarium cements are not suitable when acids are used.

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