PREPARATION OF SINTERED PYREX GLASS AERATORS FOR USE IN WATER CULTURE EXPERIMENTS WITH PLANTS

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(WITH FOUR FIGURES)

In growing plants under water culture conditions it is frequently important, and sometimes indispensable, to pass air under pressure through the solutions. Such aeration has a profound influence on root development. A practical problem arises of providing means for the uniform distribution of air through the culture solution, especially when tanks or other large containers are employed. In some experiments it is also necessary that the aeration devices shall not yield impurities to the solution; for example, in the study of the effects of elements required by the plant in minute quantity.

It has been found essential to the work of this laboratory to provide extensive facilities for aeration in the greenhouse. Several methods of distributing air were devised but were eliminated for various reasons. Among the devices used were surgical rubber tubing; porous porcelain, alundum, and block tin tubing; Folin tubes; and carborundum blocks. Surgical rubber tubing with a soft smooth wall, pierced with fine needle holes, aerated solutions fairly well, but was discarded because of its rapid deterioration, uneven aeration, and compositional impurities. Block tin tubing, drilled with small holes, was rejected because of uneven aeration and possible toxicity. The principal objections to alundum, porcelain, and carborundum were mechanical unsuitability and possible presence of impurities, both in the aerators and in the connections necessarily employed.

Since inert, resistant units of uniform quality[1] and capable of dispersing the air in fine bubbles were essential, pyrex glass was finally chosen as a suitable medium through which air could be distributed without encountering the objections mentioned. Glass aerators of the type needed were not obtainable on the market, and as methods described in the literature were not applicable to our requirements, it was necessary to develop one.

Many modifications of sintered glass aerators were tried, such as sintered disks sealed into glass tubing of various sizes and shapes, and tubing constructed entirely of sintered glass. Individually these were satisfactory in operation, but could not be economically produced in large quantities and it was difficult to obtain even aeration throughout a group of aerators. The method finally devised incorporates the sintering and sealing in one operation. The resulting aerator is efficient, rapidly and easily made in large quantities, and readily cleaned.

[1] Certain types of glass contain substances such as zinc, etc., undesirable for certain experiments.

Several steps were involved in the production of these aerators, namely, grinding the glass, grading it into sizes by elutriation and sifting, preparing a suitable receptacle, sintering the ground glass within the receptacle, and finally calibrating the sintered elements.

Grinding was accomplished by breaking pyrex glass in an iron mortar; grinding in an ordinary coffee mill equipped with steel plates, until the maximum diameter of the particles was about 1 mm.; and finally, reducing it to a still greater state of subdivision in a steel ball mill, designed in this laboratory (**1**). Portions of 100 gm. each were milled for a period of two hours, using ¾-inch steel ball bearings. Particle size varies with the amount of glass taken, the size of the mill, the diameter and weight of the balls used, and the time of grinding.

The powdered glass was then washed for three hours in an hydraulic elutriator (**2**) as suggested by Professor KIRK, of the Division of Biochemistry, and modified in our laboratory. The rate of water flow through the elutriator was controlled by means of a mercury manometer. When water was passed through at a rate of approximately 300 cc. per minute, the glass particles taken from the different compartments were found to be graded into sizes suitable for general use. When experiments necessitated the use of more closely graded aerators, however, it became essential subsequently to sift the glass mechanically into more uniform size. The glass was then treated with hot 15 per cent. sodium hydroxide solution, washed with water,

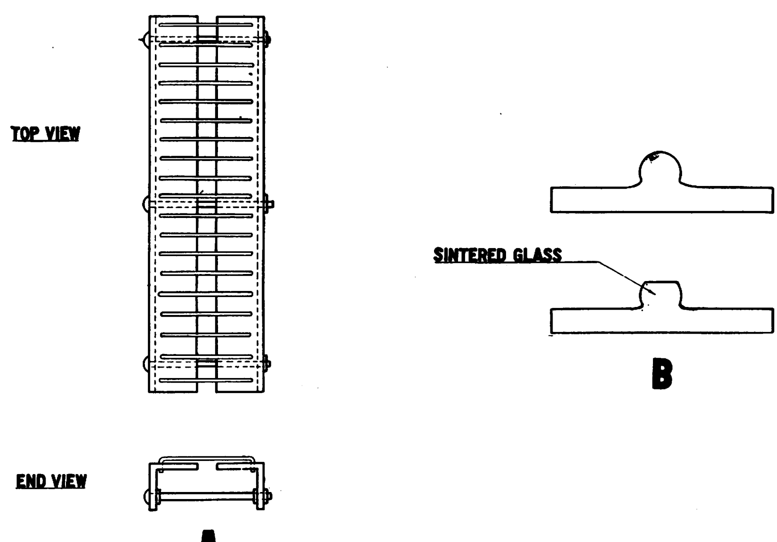

FIG. 1. Equipment and stages in preparation of sintered glass elements: *A*, rack for holding elements during sintering; *B*, glass elements showing bulb receptacle and completed unit.

digested on a steam bath with 40 per cent. (by volume) hydrochloric acid to remove iron particles and other impurities derived from the grinding process, and finally rewashed with water.

The receptacles were made from short lengths of 7-mm. pyrex tubing, a thin-walled bulb being blown in the side as shown in figure 1, *B*. A thin-stemmed funnel was used in filling the bulb, the glass being slightly heaped up to compensate for contraction during sintering and to increase the mechanical strength of the element. The powdered glass was settled in the receptacle by tapping the end of the tube. These tubes were placed, bulb down, on a black iron rack constructed of angle iron (fig. 1, *A*), the rack having previously been dusted with powdered talc to prevent adhesion between the iron and the tubing.

After the muffle had reached the proper temperature, the rack of units was inserted. The temperature immediately fell about 50° and approximately one-half of the total time of sintering was required for the muffle to reach again the initial temperature. The temperature was then held within 2–3 degrees throughout the remaining period, and the rack withdrawn. The total time of sintering, from the time of insertion, was 15 minutes.

The sintering temperatures for the three general elutriator sizes are 770°, 780°, and 790°, for the 40, 45, and 60-mm. compartments respectively

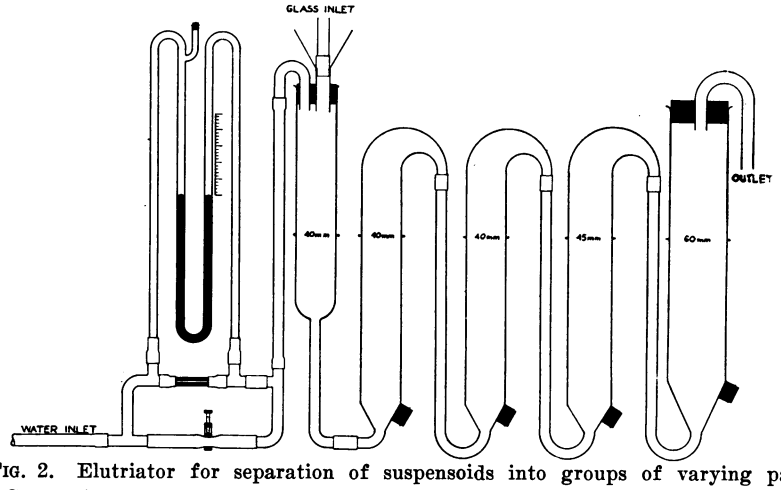

FIG. 2. Elutriator for separation of suspensoids into groups of varying particle size. Suspensions may be removed at desired intervals through the stoppered outlets at the bottom of each compartment, which are 30 cm. in height.

(fig. 2). The porosity, particle size, and sintering temperature of the graded aerators are related in the manner indicated in the following table. Upon cooling, the tip of the bulb was removed on a fine carborundum or emery wheel.

PARTICLE SIZE MESH PER INCH	AVERAGE POROSITY (CM. H_2O)	TEMPERATURE (°C.)
170–200	100	772
150–170	90	780
120–150	80	787
100–120	70	793
80–100	60	800

Sintered glass disks may be prepared in a similar manner, using a talc (soapstone) mold of suitable size equipped with a cover of the same material. The time of sintering in this case, however, must be increased to 20 minutes (for ¾-inch diameter disks).[2] These disks may be sealed in tubing of appropriate size and used where large quantities of air must be distributed (**3, 4, 5**).

Individual aeration elements were calibrated to an arbitrary rate standard of air flow. They were classified in average porosity according to the

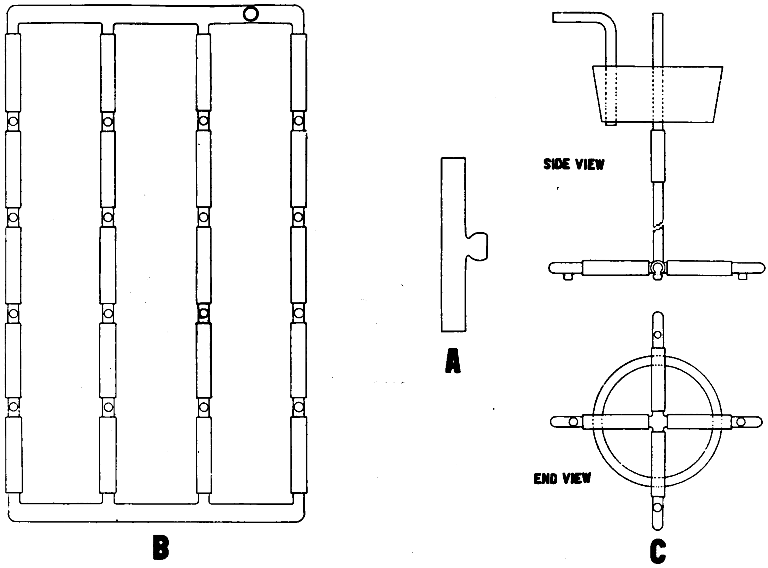

FIG. 3. Adaptations of sintered glass elements to certain aeration requirements for plant cultures (all parts are glass with rubber connectors): *A*, sintered element; *B*, assembly for use in aerating sets of plants during preliminary growth period or in subsequent experimental absorption periods; *C*, assembly for use in bottles or jars, in closed systems. This arrangement has been used effectively in respiration-absorption studies with excised root systems.

[2] An open brass mold dusted with powdered talc has recently proved itself more advantageous.

pressure in centimeters of water required to give the desired rate of flow. This method was found to be sufficiently accurate for most purposes, but when several aerators were to be operated in parallel, they were matched by a substitution method, the aerators being taken from a single calibrated group.

Aerators may be placed in series of multiples, depending upon the type of container used (figs. 3, 4). For special experiments such as those

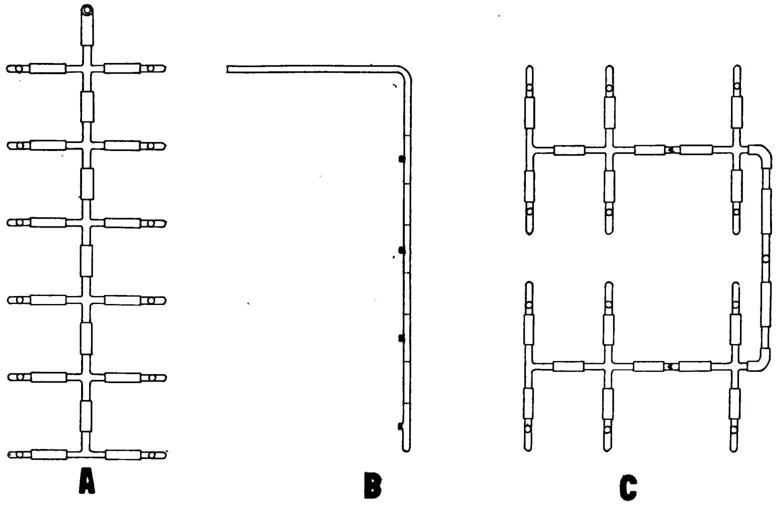

FIG. 4. Adaptations of sintered glass elements to certain aeration requirements, particularly plant culture experiments during growth periods: *A*, 12 unit assembly of glass and rubber connectors. This arrangement was designed to operate in tanks containing 12 plant groups, each effectively aerated by its corresponding underlying aerator; *B*, all-glass assembly composed of elements sealed to each other in series. This arrangement was designed for special plant culture studies where rubber or other impurities might vitiate the conclusions; *C*, sketch showing adaptability of units to multiple assemblies.

involving the use of zinc- or copper-free culture solutions, the glass aerators were sealed to pyrex tubing of the same diameter and bent to fit the container. (All rubber tubings tested in this laboratory were found to contain variable amounts of zinc and possibly other impurities.)

Precipitates formed in culture solutions may cause the rate of aeration to diminish or finally to cease entirely. When thus clogged, the aerators may be cleaned by brushing, or, in extreme cases, by digesting in warm dilute hydrochloric acid.

Aerators of this type have been in continuous use for more than a year and many are still giving satisfactory results.

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