changes should be made only after careful comparison of growth results.

One very important consideration for any growing medium is freedom from disease. Ideally, the mix will be steamed or fumigated prior to use. This is a necessary part of soil mix preparation.

MODERATOR TICKNOR: Our next speaker, Mr. Fred Petersen, is from the same firm. He is going to talk on the subject of aerated-steam. Fred:

COMMERCIAL APPLICATIONS OF AERATED STEAM

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STEAM-AIR OR AERATED-STEAM. These terms are used to describe a system or method of soil treatment in which treatment is obtained by exposing soil to a mixture of steam and air. The temperature of the resulting mixture is controlled below 212°F. by adjusting the ratio of steam to air according to established physics. While any treatment temperature between that of ambient air and 212°F. is possible, the temperature range between 140°F. and 160°F. appears most ideal.

PROGRESS. If measured by the number of successful installations now operating at high efficiency, and yielding daily benefits to nurserymen, such progress in my opinion can be summarized as:

California — Disappointing to a point of concern.
England — Encouraging as expected, since the concept is British.
Australia — Enthusiastic, as evidenced by the manner in which Australian growers installed systems after a brief, but complete, introduction to the benefits aerated-steam offers.
Eastern United States — Encouraging, as indicated from fragmentary reports.

However, if progress is measured by the quantity and quality of words already spoken or written, such progress would in my opinion, place California in a paramount position. Paramount, I maintain, because of the excellent papers and speeches which have been presented to California growers by many experts, foremost of which is Dr. K. F. Baker of the University of California at Berkeley.

Nurserymen the world over have been literally blessed with much of Dr. Baker's early work, the most familar of which is his editing of University of California MANUAL 23, the *UC SYSTEM FOR PRODUCING HEALTHY CONTAINER*

GROWN PLANTS, published in 1957(1) Section 10 of this Manual contain these words which are as applicable now as they were in 1957:

"Any successful mechanized nursery program must include, indeed must be built around, soil treatment".

In Section 9 brief mention is made of aerated-steam, concluding with the statement:

"This method is not yet ready for commercial application".

Steam and its ramifications have been discussed thoroughly by others. Why then is it important for us to re-focus our attention on this time-old subject? For the following reasons:

1. Toxins are often released from soil mineral and/or organic constituents by high temperature treatment. This effect is virtually eliminated at lower temperature treatment. (Manganese toxicity is a common problem at the higher temperatures.)
2. Although all pathogens are killed at 140° F., many saprophytic organisms survive. These remaining organisms constitute a biological buffer against chance re-invasion by plant disease organisms. At higher temperatures most of the saprophytes are killed.
3. Spores of certain dormant saprophytes may, by low treatment, be induced to germinate, thus increasing the biological buffer.
4. Many plastic containers can be exposed to temperatures up to 160°F. without damage. Soil treatment in plastic containers has not been possible at the higher temperatures.
5. It takes less energy to raise the soil to a temperature of 140°F., hence the average savings in steam (and therefore cost) can be as high as approximately 50%.

To achieve these benefits soils are best treated with aerated-steam.

How do we obtain this material labelled aerated-steam? Who sells it? What equipment is required? What does it cost? Answers to these and other questions can be found in the following publication which I encourage you to obtain and study: Proceedings: *TURF, NURSERY AND LANDSCAPE TREE CONFERENCE*. University of California — Davis, California, February. 1966.

Dr. Baker writes in his paper: "Growers can now heat soil, stationary or moving, to any desired temperature in any of the standard equipments used in California", and: "aerated steam is thought to be complicated and difficult to use. The only additional equipment involved is a blower. Operation is similar to, and no more complex than use with ordinary steam. Grower experience is in accord with this fact".(2)

Mr. Robert Brazelton, Extension Engineer of the University of California, Agricultural Extension Service, follows Dr. Baker's paper with an excellent discussion of the subject from an engineering point of view. The specific system he de-

scribes was designed by Laboratory personnel following an earlier design reported by F. W. Taylor in Australia. Mr. Brazelton's paper contains sufficient information to permit any mechanically-inclined nurseryman or well-advised welder to construct satisfactory equipment. Mr. Brazelton wisely states advice I would repeat and encourage you heed: "Do not, however, think that if you wait 2 years, the bugs will be ironed out, and you will have necessarily gained an advantage, because the units as they are now designed are sufficiently efficient and durable to be classified as unqualified successes as is". (2)

HISTORICAL REVIEW

1954-1955 — English work on the subject of aerated-steam by Morris and Bunt was discussed in UC Manual 23. (1)

1957 — U.C. Manual 23 was published with all of its ramifications regarding steam sterilization.

1961 — Dr. K. F. Baker, on leave at the Waite Agricultural Institute, Adelaide, South Australia, published: Principles of Heat Treatment of Soil and Planting Material. (3) This paper led to F. W. Taylor's work: *A Method for Heat Treatment of Soils Using Steam and Air Mixtures at 140°*. (4) This work by Taylor described and contained plans of a system installed at Paramount Nurseries in Australia.

1962 — Dr. John Ferguson and Mr. Paul Ecke, Jr. described a steam-air system utuilizing a Venturi. (5) This approach has since been, for all practical purposes, discarded because of lack of precision, back-pressure problems, and cost.

1962 — At Brown Bulb Ranch, Capitola, California, the first known vault-type aerated-steam system in California was installed. Total modification cost to an existing vault was approximately $50.00. In-field tests were performed by Dr. Carl Olsen, then a graduate student of Dr. Baker's at Berkeley. This system is in use and is yielding excellent results, particularly in the treatment of seedling flat media.

1963 — Our Laboratory published a brief note in an advisory form to our clients pointing out key factors involved in aerated-steam.

1963 — At Kitagawa Nursery in Redwood City, California, the first known California-built bulk type soil treatment system, patterned from Taylor's paper, (4) was constructed by Mr. Richard Kitasoe, owner of Kitagawa Nursery. This system was evaluated by Dr. Arthur McCain and Dr. R. H. Sciaroni. (6) Though describing the system as installed, and reviewing some aspects of aerated-steam, their work apparently did not stimulate significant progress. The key points of biological antagonism and potential toxicity reduction were apparently overshadowed by the paper's stress upon chemotherapy methods.

1964 — At Sunnyside Nurseries in Hayward, California, a large vault-type system for treating flat material was con-

structed. This system still requires substantial modifications to overcome present well-understood defects including: high radiation loss through steel walls, excessive size, and noise. This system, however, did demonstrate the practicality of treating plastic containers, and in-field tests conducted by Dr. Baker, Dr. Olsen, and Mr. Bill Fuller of the Department of Plant Pathology, University of California, Berkeley, indicated extremely uniform temperature distribution, and basic conformance to principles.

1965 — A system utilizing a concrete mixer was described by Griffin, Maire and Humphrey in University of California Agricultural Extension Publication AXT-177.(7) The concrete mixer method has the obvious advantage of being an extremely inexpensive system. This approach, however, may have the deficiency of a prolonged cool-down period introducing the possibility of over-kill. The quality of temperature control, and of temperature measurement are also of some concern, since the treatment container is constantly in motion.

1955-1966 — At Azalealand Nursery in Mt. View, California, the owner — Mr. Mario Pocchini — constructed a portable, bulk-treatment trailer, specially designed for treatment of peat moss. Design parameters were established by the Laboratory following Taylor's basic concepts,(4) as further modified by the suggestions of Dr. Baker, Dr. Olsen, and Mr. Brazelton. Performance tests were made by Dr. Baker, Mr. Bill Fuller, and by Mr. Brazelton who had earlier provided valuable back-pressure data. Test summaries and conclusions indicated several advantages of the Azalealand unit, including:

(1.) The portable nature and tilt-down side design permits its use as a potting bench.
(2.) The plenum chamber aerated-steam introduction technique permits rapid "turn-around" time, since media rises to the treatment temperature in approximately 20 minutes, and can be cooled to ambient temperature in approximately 40 minutes after the treatment period. Potting, therefore, is practical 1½ hours after loading.
(3.) The design yields excellent temperature control, and distribution of heat once the desired treatment temperature is reached.
(4.) With a minimum of further investment, such a system could be completely automated.

Materials of construction could quite likely be improved in further units of this type, as more specifically detailed by Mr. Brazelton in his paper presented on this subject.(2)

SUMMARY — The use of aerated-steam is probably the most significant pathological soil treatment advance in nine years. It is unfortunate that more widespread advantage has not been taken of this opportunity.

In retrospect, several factors have apparently combined

to limit more common useage of the aerated-steam technique. These factors probably include.

(1.) Delay and procrastination on the part of our firm in publishing results such as were obtained with the Azalealand unit reviewed by Brazelton.(2)

(2.) Apparent lack of physical capability of the Agricultural Engineering Department of the University of California. Resources of this Department are seemingly strained, and if supplemented in the future, additional capability could probably be developed utilizing the skill and efficiency of the present staff whose enthusiasm was amply demonstrated by the assistance rendered in the Azalealand project.

(3.) Lack of demand from the growers best summarized by the "Let the Other Guy Go First" philosophy.

(4.) Hesitancy on the part of industrial suppliers of required equipment. Many suppliers contacted saw an apparently limited market for equipment, and because of economics would not devote a substantial research and development effort. As demands increase, and sales projections rise, industry can hopefully be encouraged to devote a greater share of research and development capability in this direction. The result could be availability of complete, professionally engineered systems.

THE FUTURE — At the present time the "Let The Other Guy Go First" philosophy does not appear to offer a valid excuse for lack of progress. Though imperfect in some ways, the systems now in use have provided a sound basis from which other growers can logically proceed. The expert comments and advice of Mr. Brazelton and Dr. Baker would appear to substantiate this. Additional efforts by the University of California, Agricultural Extension Service, in communicating and expanding upon information already developed would also be helpful to California growers who depend heavily upon the communications and advice of the Extension Service at the Farm Advisor level. Farm Advisors in California undoubtedly would be pleased to render additional service in the future depending upon the climate of reception at the grower level. It would appear, therefore, that not many new words can be found, but that many new systems can be constructed.

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MODERATOR TICKNOR: Thank you, Fred, for a most stimulating discussion. Now we will have Dr. Falih Aljibury speak to us on controlled-release fertilizers.

CONTROLLED-RELEASE FERTILIZERS

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In recent years there has been considerable interest in the use of the so-called "slow-release" or "controlled-release" fertilizers. The use of such products has offered several advantages:

(1) They can be applied at the rate required by the plants without causing excessive loss by leaching.
(2) The nature of the release allows for reasonable mistakes and over-application without burning the plants.
(3) Frequent application of fertilizers will not be required.

The characteristics of the slow-release and long-lasting fertilizers described in this paper are attributed to the following techniques:

A. *Membrane Coating.* Fertilizers are coated by membranes of various sources and thickness. When the fertilizers are in contact with moist soils, water enters through the membrane and dissolves some of the fertilizers in the capsule. The dissolved fertilizers diffuse out of the membrane into the surrounding soil. The rate of release is manipulated by the thickness of the membrane. This technique may provide a release rate of one to two per cent per day.

B. *Metal Ammonium Phosphates* — Divalent metals such as magnesium, ferrous iron, zinc, manganese, and copper can be found in slowly soluble compounds. When the fertilizer comes in contact with water, it dissolves until saturation. When the nutrients are used up by plants, the equilibrium is upset and thus more fertilizer is dissolved. The rate of release is influenced by pH and the degree of soil wetness. The rate of release is also influenced by the size of the particles and the method of application. Incorporating the fertilizer in-