N86-19916

PLANT GROWTH CHAMBER 'M' DESIGN

Ralph P. Prince, Environmental Engineer and
William M. Knott, Ph.D., Biological Sciences Officer,
Biomedical Office, NASA, Kennedy Space Center, FL 32899
FTS 823-3152, Commercial 305-867-3152

INTRODUCTION:

Crop production is just one of the many processes involved in establishing long term survival of man in space. The benefits of integrating higher plants into the overall plan was recognized early by NASA through the Controlled Environment Life Support System (CELSS) program. As it continues to explore the fundamental concepts of plant life, plans are to develop the capability for integrating the biological, physical, chemical and control components into a working ground-based unit.

The first step in a sequence of activities planned for the John F. Kennedy Space Center is to design, construct, and operate a sealed (gas, liquid, and solid) plant growth chamber. A 3.6m diameter by 6.7m high closed cylinder (previously used as a hypobaric vessel during the Mercury program) is being modified for this purpose. The chamber is mounted on legs with the central axis vertical. Entrance to the chamber is through an airlock. It is located in Hangar L on the Cape Canaveral Air Force Station. This chamber will be devoted entirely to higher plant experimentation. Any waste treatment, food processing or product storage studies will be carried on outside of this chamber.

Its primary purpose is to provide input and output data on solids, liquids, and gases for single crop species and multiple species production using different nutrient delivery systems.

INTEGRATION PLAN

The food production component will become the central focus for the food processing, food preparation, solids and liquids waste treatment, gas regeneration, storage, and monitoring and control components. Data resulting from this food production unit will be used in the design and operation of other components. This chamber is expected to be operational in March 1986.

CHAMBER DESIGN

Physical Features. The chamber is 3.6m (12 ft.) diameter by 6.7m (22 ft.) high containing $68m^3$ ($2500\ ft^3$). Approximately $25m^2$ ($250\ ft^2$) of conventional crop growing area can be obtained by dividing the chamber into 2 sections with 2 growing levels each, as shown in Figure 1. This chamber should produce enough edible dry matter to supply one-half of the diet for a person based on a production rate of 10g/m^2/day (Tibbitts and Alford, 1982) and a consumption of 500g of edible dry matter per day. A solid floor between levels will permit different radiation treatments to be conducted even though all of the other parameters will not be affected. Crops can be grown around the periphery of the chamber leaving the center clear for work, a lift and a ladder.

Temperature and moisture regulation for the growing area and for the lamp banks will take place outside the chamber. The chamber is to operate at .5 kPa (2 in H_2O) pressure and chamber air will to be circulated through absolute filters. Carbon dioxide will be from bottled gas and air will be exchanged with the atmosphere.

To accommodate tall crops the lower lamp banks on each level will be removable. All crop support shelves will be adjustable from the lower position to within .56m of the lamp bank. The walls will be finished with mirrored surfaces.

Safety measures will be designed and built into the chamber to take care of equipment failure and human accident. Television cameras will monitor both levels.

SCHEMATIC OF JFK PLANT GROWTH CHAMBER

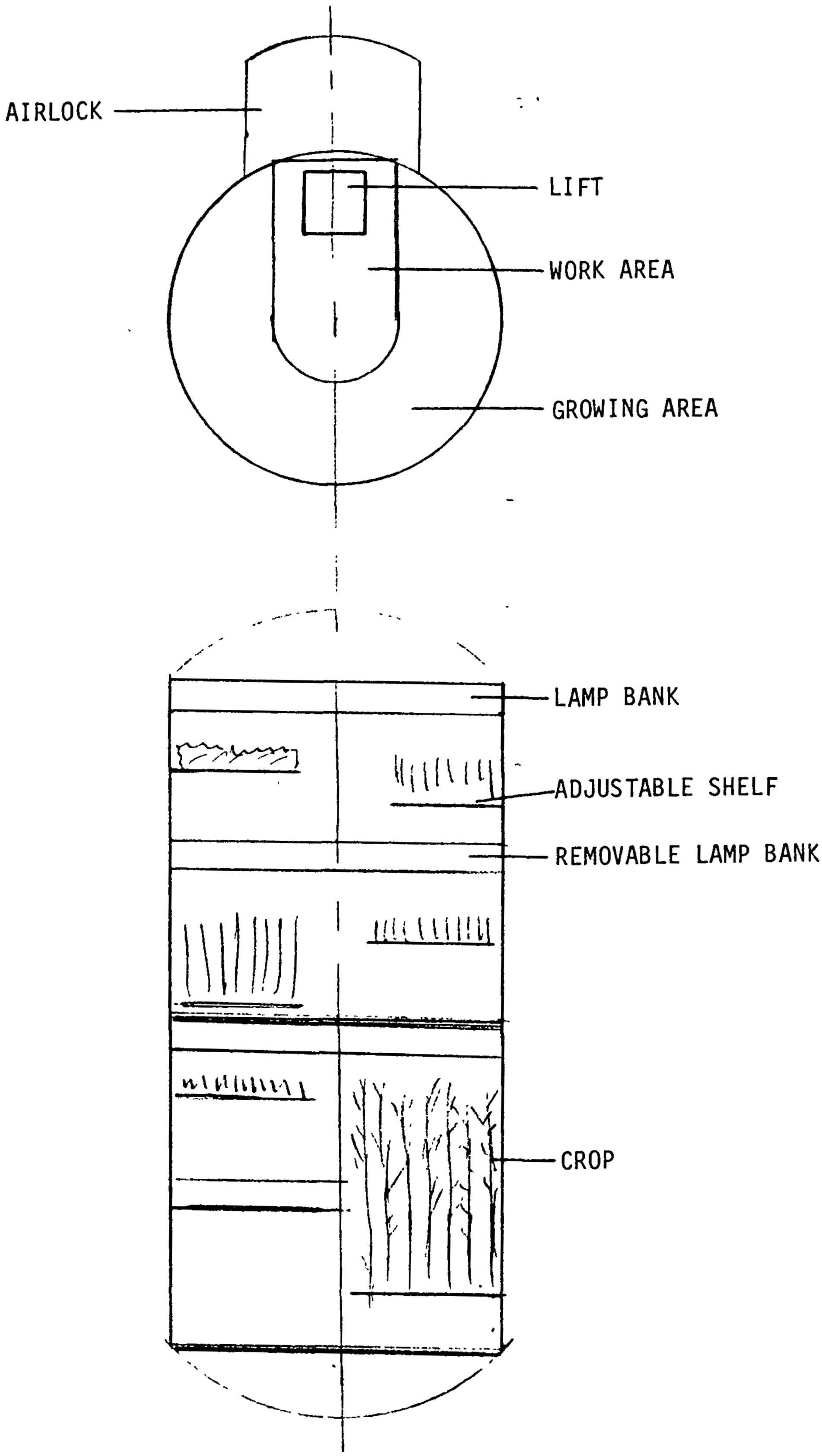

FIGURE 1

Growth Parameters. Because of the need to grow many different crops, the limits on essential growth parameters were set as shown in Table 1. The limits will permit a wide spectrum of experiments to be conducted. It will be possible to maintain two light regimes on the two levels of the chamber. Temperature, moisture, and carbon dioxide will be uniform throughout the chamber. Nutrient solution composition, concentration, pH and temperature can be specified as can nutrient quantity per plant, and nutrient velocity past the plant root when using a film.

Nutrient Delivery System. A conventional nutrient delivery system will be used for the initial plant growth experiments. It will be flexible allowing for type of growing systems (trough or pipe, gulley, and tube) and modes of production (continuous and all-in/all-out). Specific requirements for the particular crop and experiment can be met.

Experimental nutrient delivery systems such as the Capillary Effect Root Environmental System (CERES) (Wright and Bausch, 1984) will be studied. Crop production will be used as a part of the overall evaluation on nutrient delivery systems.

Table 1. Environmental parameters to be monitored and controlled in the plant production compartment.

PARAMETER	LIMIT LOW	LIMIT HIGH	Max. CONTROL ERROR	Min. MONITOR SENSITIVITY
Photosynthetically-active radiation at plant level ($\mu mol \cdot s^{-1} \cdot m^{-2}$)	200	$\geq$1000	NA	NA
Photoperiod (min)	species-specific	continuous	1	NA
Temperature (C)				
light	15	40	1	0.2
dark	10	30	1	0.2
Humidity (%RH)	60	$\geq$90	7	2
Carbon dioxide (ppm)	300	$\geq$2500	10	10
Oxygen (ppt) (added or scrubbed)	control to $\leq$20.9%		10	5
Air movement across leaf canopy ($m \cdot s^{-1}$)	2	5	NA	0.1

MONITORING AND CONTROL

It is necessary for this chamber to furnish data on energy, solids, liquids, and gases. Inputs and outputs of solids and liquids for the various experiments can be obtained.

Continuous monitoring of oxygen and carbon dioxide will insure that crop growing conditions are maintained. Periodic sampling of ethylene and other gases (Table 2) will provide information on specific crops, multiple crop species, and processes needed for future studies.

Initially, service personnel will wear face masks that are supplied with outside air. Later in the program, and as experiments dictate, complete suits may be worn by personnel entering the chamber which should permit a complete thermal, moisture, and gas analysis.

EXPERIMENTS

It is imperative that performance of the chamber be evaluated with a single crop species. Bush beans have been suggested as a good candidate for this first crop. Other crop species, modes of operation, and nutrient delivery systems can be added as confidence is gained with analysis of the system operation.

Table 2. Gases and particulates that should be controlled and/or monitored in the test chamber.

GAS	EXPECTED CONC.	MIN. INSTR. SENS.
Oxygen	20.9%	0.1%
Nitrogen	78.1%	0.1%
Carbon dioxide	300 to $\geq$ 2500 ppm	10 ppm
NO		
NO_2		
N_2O		
Ozone		
CO		
Ethylene		
H_2S		
Neon		
Ammonia		
Chlorine		
Fluorine		
Formaldehyde		
Methane		
Propylene		
Propane		
Vinyl Chloride		
Terpenoids and oils		
Krypton		
Freon		
(others as discovered)		
Pollen		
Mold Spores		
Dust		

Experiments designed to maximize volume utilization, minimize energy requirements, and minimize water useage are important. Others to determine the initiation points of toxic substances (solid, liquid, and gas) will be studied if needed. Studies to evaluate shoot-to-root, and edible-to-non-edible ratios need to be conducted. A careful assessment of food and oxygen production per unit of area and per unit of volume for several crop generations must be made. These data will provide a base for further research and for a more deliberate design of future food production components.

This chamber will contribute toward the detailed understanding of water (condensate, transpired, nutrient solution, and plant) recycling, biomass treatment, and gas regeneration. It will become the test-bed for controlled processes leading to recycling of solids, liquids, and gases.

Crops destined for study and evaluation include: beans (bush), wheat, potatoes, soybeans, rice, carrots, cowpea, winged bean, etc. These are some of the crops listed by Tibbitts and Alford, 1982.

REFERENCES

Tibbitts, T.W., and D.K. Alford. Controlled Ecological Life Support System - Use of Higher Plants. NASA Conference Publication 2231. 1982.

Wright, B.D., and W.C. Bausch. A Plant Growth System for Oribtal Plant Experiments. Paper No. 84-2524. ASAE. St. Joseph, MI. 1984