CONSTRUCTION OF INEXPENSIVE, WALK-IN ENVIRONMENTAL CHAMBERS FOR STUDYING INSECT-TEMPERATURE RELATIONSHIPS[1]

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ABSTRACT

The construction of walk-in controlled environmental chambers that achieve high accuracy at low cost is described. These chambers are capable of maintaining air temperatures at 15 - 35° ± 0.5°C. Long term (weekly) humidity stability averages 75% RH at ± 6%. The described units are useful for large-scale bioassay experiments.

Key Words: Temperature, environmental chamber, walk-in, inexpensive.

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INTRODUCTION

Researchers have long recognized the importance of valid environmental simulations when observing and quantifying insect responses to a particular set of conditions. Many ecologically oriented experiments, particularly those related to development of simulation models, require many observations of a particular insect-plant response at a controlled temperature. Although there are many walk-in environmental chambers available commercially, their high cost and small size are often prohibitive for many research projects.

This paper describes the construction and design of temperature controlled chambers recently assembled at Mississippi State University which closely match the temperature specifications of commercial units. The total cost, as of July, 1983, for each completed unit was $2,934 (includes 82 manhours labor @ $5.00 per hour). The design is simple, and units can be assembled by lay workers.

MATERIALS AND METHODS

Cabinet Construction

The size of the unit devised is flexible, and modificatons can be made to meet individual requirements. Capacities of air conditioning and heating equipment can be increased or decreased depending upon cabinet size requirements. Our interior dimension measured 1.52 × 2.44 × 2.29 m (8.5 cubic meters). The materials selected for construction of the cabinet (Fig. 1), were chosen for ease of construction, durability, and low cost.

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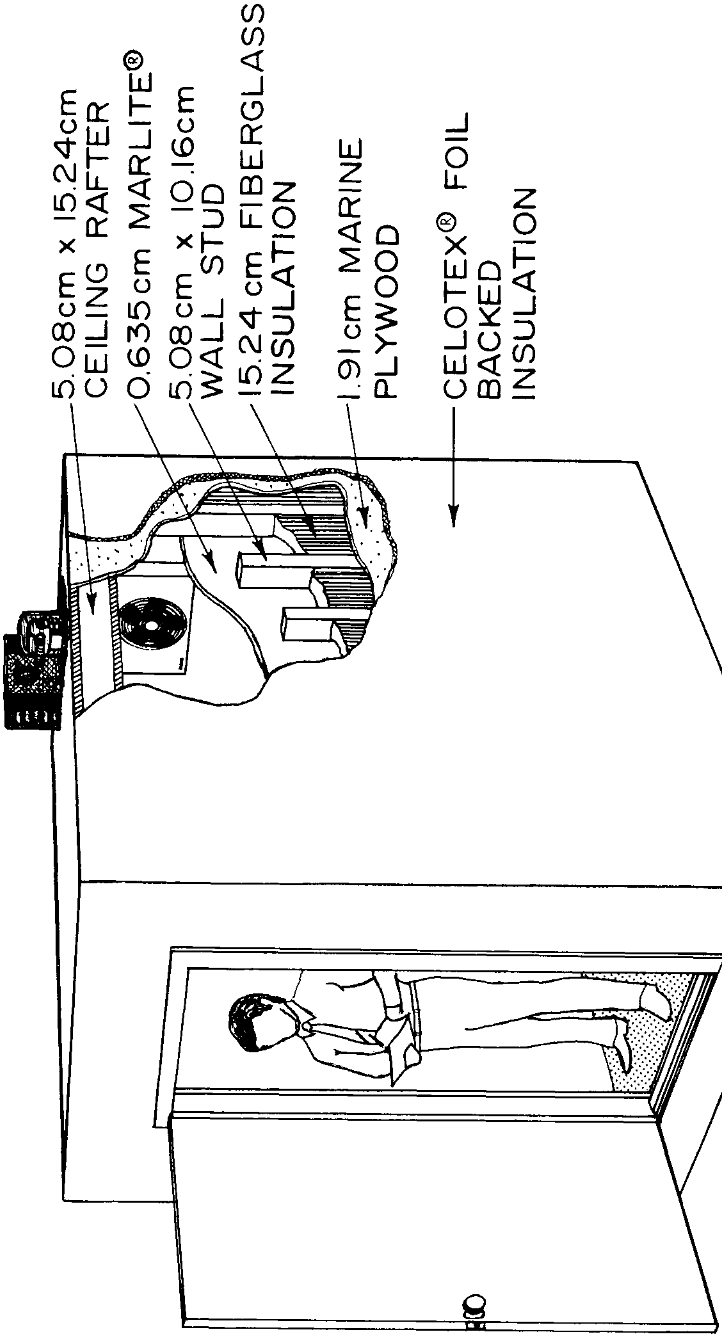

Fig. 1. Composite drawing of finished structure.

Standard carpentry procedures were followed in assembling the cabinet shell. All construction components should be readily available at local hardware stores. Marine plywood (1.91 cm) was used for exterior walls, and 5.08 × 10.16 cm fir studs were set on 40.64 cm centers along all walls. The floor and ceiling were assembled with double walled construction (1.91 cm plywood — 5.08 × 15.24 cm joists — 1.91 cm plywood). During construction, all seams were sealed with latex caulking to insure a tight seal. Interior walls were covered with 0.635 cm Marlite® panels which may be cleaned with water. The Marlite® panels were secured with moulding brackets and all seams were again sealed with latex caulking.

Industrial quality vinyl flooring was glued to the sub-floor. A 0.635 cm foam underlay was used under the vinyl as an extra measure of insulation. A 6.35 cm flush-mount drain was installed in the floor to facilitate easy cleaning and disinfecting of the walls. Removable brackets and shelves were installed on the interior walls to accomodate various experiments.

Proper insulation was important because of the stable temperature requirements of most experiments. Fiberglass insulation (15.24 cm) was installed between all studs and joists in the walls, ceiling, and floor. The fiberglass insulation had a resistance (R) value of 17. The outside of the chambers was covered with 1.91 cm foam insualtion, commonly called Celotex® which were double foil backed and had an R value of 12. All outside seams were caulked and then sealed with aluminum foil tape. The addition of the R values of all the insulation and lumber gave the cabinet a total R value of 34.

The design and seal of the entrance door was very important because it was a possible source of air escape and temperature exchange. After considering several options, we selected a Stanley® Model RD1 insulated steel door with a R rating of 15.5, the highest found. The door was easily installed, and magnetic weatherstripping was used to form an airtight seal that prevented air infiltration and/or loss. Humidity problems associated with wooden doors (warping) are not encountered with this steel clad door.

Temperature Control

Several refined temperature control units are available commercially at varying price ranges. Although complete units are available, we chose to use a "built-up" system (different manufacturer components) to achieve our specific needs at a lower cost. The Tecumsh® Model AE 4430 AC was chosen for the air-cooled condensing units. It is rated at 1/4 h.p., operates on 115 volts and has an output of 2830 BTU/hr. The evaporator coil chosen was a McQuay® Model CSM031A forced air, with a capacity fo 395 cubic feet per minute capacity operating on 115 volt high phase. The evaporator coil was installed on the interior upper wall. To obtain the minimum force concept, the refrigeration compressor is operated continuously in the cooling mode. The thermostat control system activates a 750-w resistance heater element mounted on the evaporator coil when more heat is needed. A stable temperature is achieved by cycling only the on-off time of the heaters, preventing thermal shock that results from a cycling compressor. Although compressors are normally cycled, a Sporlan® expansion valve (Model FF-1/4) was installed to allow the refrigerant pressure, and thus the cooling capacity of the compressor, to be adjusted by the operator.

A Honeywell® transformer, Model AT72D1683 was used to stepdown for low voltage wiring for controls and relays. An Essex/Stevens® model 90-104 was chosen for the (RBM) relay. For the thermostat, the Honeywell® Model T678A two-stage insertion which provides 2-stage low-voltage switching for control of air temperature was chosen. It contains two spdt switches operated by a single temperature-sensing element. Each switch has a fixed differential of approximately 0.5°C. The right-hand switch operates at a lower temperature than the left-hand switch. This difference in operating temperatures of the two switches is called the "interstage differential." For greater accuracy, closer interstage differential switches may be substituted.

By selecting appropriate terminals on the thermostat switches, the switches may be used to make or break the controlled circuits on either temperature rise or fall; or to connect one circuit and break another as temperature changes from set point. Mounting the sensing bulb in close proximity to the heating element results in adequate sensitivity at very low cost. Since the sensing unit is so close to the heater, cycling occurs at a rapid rate and increases or decreases the chamber temperature very slowly, resulting in a stable temperature.

Humidity and Light Control

As of printing, a humidity control was not yet installed on the units. For our initial research purposes, the 70 - 75% RH of the chambers was sufficient. Addition of humidity controls to the existing unit may be easily accomplished if varying humidity ranges are needed. Several companies, such as Carrier, McQuay, and York, have commercial units which will adapt readily to the present equipment. If cost is a factor, small portable units may work satisfactorily. The lighting system consists of four 15-w Westinghouse Agro® lights and two standard soft white lights in an above chamber mount. The lights are cycled by a standard 24 hr Dayton® timer. A single 50-w infrared bulb was installed overhead and is used as a work light when observations were needed during the night phase of the light-dark times. Three 110-volt outlets were installed on the interior walls for convenience when using electrical equipment.

RESULTS AND DISCUSSION

Jackson (1960), Wagner et al. (1965), Wharton and Knulle (1966), Atmar and Ellington (1972), and Wilson and Stinner (1981) all designed or improved environmental chambers. Our chambers differ from those previously in that they will accommodate larger scale bioassay experiments.

Since researchers need to monitor experiments for long periods of time, we tested the stability of our units. The chambers were set at various temperatures and allowed to operate continuously for a period of one week. Each chamber was monitored by a remote hygrothermograph placed inside each unit. Results are shown in Table 1. The chambers are capable of maintaining stable air temperatures from 15° - 35°C with ± 0.5°C accuracy (Table 1). Reduction of the thermostat temperature differential for greater accuracy may be possible, but at a greater cost. Periodically, during experiments, it is also necessary to enter and exit the chambers for routine observations. Thus, an experiment was conducted to determine what effects workers entering the chambers, doing any necessary work, and then exiting the chambers, would have on the stability of temperature. The environmental chambers were initially set at temperatures of 15, 20, 25, 30, 35°C and allowed to stabilize for two hours (Table 2). One person would then open and

Table 1. Ranges in temperature observed in environmental chambers and recorded over a seven day period.

Set temperature °C	Minimum temperature °C	Maximum temperature °C	Total drift temperature °C*
15°	14.8°	15.3°	0.5°
20°	19.7°	20.1°	0.4°
25°	24.8°	25.2°	0.4°
30°	29.7°	30.2°	0.5°
35°	34.9°	35.4°	0.5°

* Total drift temperature is the maximum temperature recorded minus the minimum temperature recorded.

Table 2. Amount of time required for environmental chamber to recover to set temperature after routine opening and closing of door.

Outside air temperature °C	Inside air temperature °C	Mean recovery time (minutes)	± SE*
28°	15°	8.0	0.57
28°	20°	6.2	0.32
28°	25°	4.3	0.24
28°	30°	5.1	0.39
28°	35°	5.8	0.41

* SE = Standard Error of Mean.

close the door, remain inside the chamber for 5 minutes, and then exit by opening and closing the door. During the experiment, temperatures were monitored by hygrothermographs, both inside and outside the chambers. Since our units are located in a temperature controlled building, the outside temperature was relatively constant at room temperature (28°C). The experiment was repeated four times at five different controlled temperatures in the unit (Table 2). We then measured the time required for temperatures to stabilize to the set temperature (Table 2). With a temperature setting of 15°C, 8.0 minutes were required after opening and closing the door for the units to stabilize. Similar recovery times at 20, 25, 30, and 35° were recorded at 6.2, 4.3, 5.1, and 5.8 minutes, respectively. Certainly these times would vary at different outside room temperatures.

Overall, these chambers have performed satisfactorily and reliably. The main advantage with chambers such as this is their size capabilities. When researchers need a stable environment for large-scale bioassay studies, environmental chambers such as these can be custom made to work at less cost than the more sophisticated, expensive commercial units.

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