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SHORT COMMUNICATION

MODIFICATIONS TO A CONTROLLED ENVIRONMENT CABINET TO GAIN PROPORTIONAL CONTROL OVER TEMPERATURE AND HUMIDITY

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Modern controlled environment cabinets with temperature control specifications to ±0·4 °C and humidity control at 20 °C of ±3 % between 55 % and 90 % are expensive. The standard cabinets available for biological work can limit fluctuations at 'constant' temperatures to ±1 °C. Humidity control is primitive and the range of humidities attainable and the accuracy with which they can be held is unacceptable. Studies in experimental biology recognize the importance of a closely controlled atmospheric temperature and moisture content in work ranging from translocation and product storage in plants to the physiology and behaviour of pests and other animals. In many of these studies saturated salt solutions are used. These are unsuitable since they can only be used with small volumes of air, access to the experimental subjects is incompatible with the maintenance of the stated humidity levels, and controlled changes in humidity are difficult to achieve.

This paper describes modifications to a Sherer Growth Chamber (Model No. Cel 37–14: purchased 1969) which improve its operational characteristics. The specification and performance of the original and the modified machine are outlined in Table 1 and Fig. 1. The cabinet has been used to study the control of rhythmic behaviour in woodlice.

A ventilated psychrometer was constructed following British Standard 4194: 1967. The wet and dry loaded thermocouples were set into a tube continuously ventilated at 1 m s^{-1}, and were used for monitoring the conditions in the chamber. Three thermistors (two dry, TH1, TH2 and one wet, TH3) were also incorporated into the tube and used as the sensors for the new control systems.

Temperature control was established by continuously refrigerating the cabinet while providing compensatory heating by proportional zero voltage switching of the power supply to the heating elements. A total of 3·1 kW of heating was installed to permit rapid transition from one temperature regime to another. The

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Table 1. *The original and modified features of the Sherer growth cabinet*

Feature	Original	Modified
Chamber volume	1·66 m	1·66 m
Temperature system		
Range	4–43 °C	7–23 °C
Accuracy	±2 °C	±0·31 °C
Controlled system	refrigerant flow to evaporator	power supply to 3·1 kW heater
Control type	on/off	proportional
Antagonist	500 W heater	continuous cooling
Sensor	bimetallic strip	thermistor
Humidity system		
Range	unspecified	70–100 % RH
Accuracy	unspecified	±2 % RH
Controlled system	centrifugal atomizer	compressed air to a spray gun
Control type	on/off	proportional
Antagonist	500 W heater	continuous condensation on the evaporator
Sensor	hair hygrometer	ventilated psychrometer

control circuit (Fig. 3A) which uses an R.S. Components zero voltage switch 305-800, is a variant of the proportional temperature control circuit given in R.S. Data sheet R/2129 and used by Buick, McMullan, Morgan & Murray (1977). (The 305-800 is being superseded and can be replaced by the zero voltage chip TDA 1024 with some modifications to the circuitry.) Control over the experimental range of 6–23 °C was achieved by adjusting the potentiometer (*P* in Fig. 3). The circuit pulses current to the heating elements for a time which is proportional to the difference between the desired and measured temperatures. The pulse frequency was set at 1 Hz (maximum pulse duration 1 s). This resulted in accurate control about the desired temperature – in practice, over the range 6·7–22·5 °C the temperature was maintained within ±0·13 °C.

A compensatory heater (*E* in Fig. 2) is required when operating the cabinet with a light/dark regime. This heater is engaged when the lights are turned off, to minimize temperature fluctuations.

Periodic temperature changes were achieved by switching between preset potentiometers at the desired time. The overall stability of the system is determined by the pulse frequency of the controller and the variations in thermal load within the cabinet.

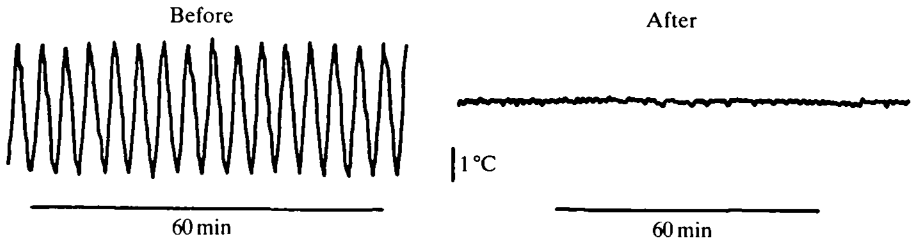

Fig. 1. Temperature variations in the cabinet before and after modification.

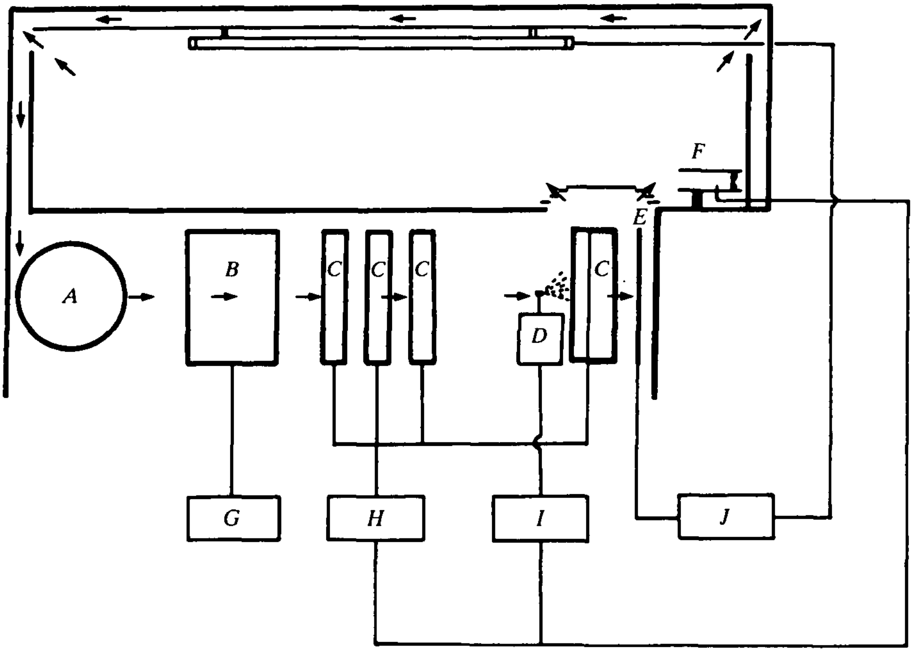

Fig. 2. The layout of the new control systems. *A*, fan unit; *B*, evaporator; *C*, heating elements (3·1 kW in all); *D*, spray gun; *E*, heating element compensating for lights; *F*, ventilated psychrometer; *G*, defrost timer; *H*, proportional controller (temperature); *I*, proportional controller (humidity); *J*, lighting control. The arrows indicate the direction of air circulation. Diagram not to scale.

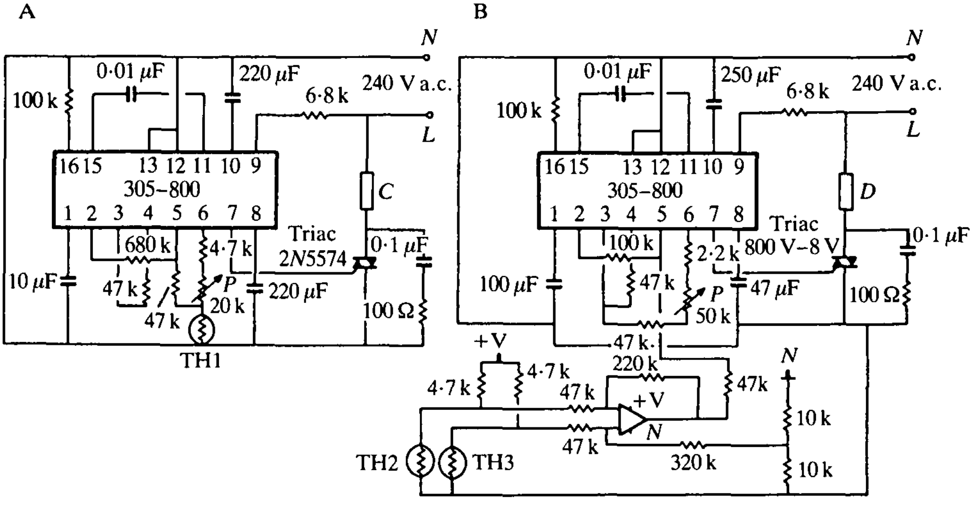

Fig. 3. Circuits associated with (A) temperature control and (B) humidity control. (+V is taken from pin 6 of the zero voltage switch 305-800). Components: TH1, TH2, TH3, thermistors. *C*, 3·1 kW heating element; *D*, solenoid controlling compressed air to the spray gun; *P*, potentiometer setting temperature or humidity; *L*—live; *N*—neutral.

The humidity control circuit (Fig. 3B) is similar to that described for temperature control. The sensor system involves the resistances of the wet (TH3) and dry (TH2) bulb thermistors, the difference between which is amplified by a differential amplifier before being passed to the zero voltage switch (305-800). The humidity controller maintains a constant difference between the resistances of the wet and dry bulb thermistors and is thus not a relative humidity (RH) controller. The maintenance of a constant relative humidity at two dry bulb temperatures requires different wet bulb depressions, the settings for which have to be determined by calibration. For a particular temperature the dry bulb potentiometer setting varies with humidity and therefore a change in humidity at constant temperature also requires calibration of the potentiometer settings for both the wet and dry bulb temperatures.

The proportional output to the load (a solenoid) vents bursts of compressed air at 138 kPa to a spray gun (*D* in Fig. 2) located down wind of the evaporator and delivering atomized water into the circulating air. The spray was preheated to 58 °C and projected onto a fine mesh associated with the final heating element to aid vapourization. The pulse frequency was set to 0·1 Hz.

Defrosting of the evaporator is necessary to maintain control efficiency for periods of a few days, and was achieved by installing a hot-gas by-pass to discharge refrigerant at 1216 kPa and 50 °C directly from the compressor to the evaporator behind the position of the expansion valve. This results in extremely rapid defrosting. A rapid defrost cycle (30 s on– 60 s off) was chosen to minimize the temperature increase during defrosting. Nevertheless the effect of the defrost cycle was to raise the lower limits of operation to 7 °C and 70 % relative humidity and to produce dry bulb fluctuations from ±0·13 °C at 7 °C to ±0·31 °C at 22 °C. The benefit, however, was in reliable long-term operation (e.g. 8 weeks at 100 % RH and 10 °C). The cycle can be varied to minimize the temperature fluctuations for the particular humidity regime required.

The modifications described allow sufficient flexibility to improve the performance of standard controlled environment cabinets to the level of the more expensive models currently available. Since the control components cost under £40 in parts, it was considered a worthwhile investment.

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REFERENCES

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