CONVERSION EQUIPMENT TO PRODUCE A CYCLIC ENVIRONMENT WITHIN CONSTANT TEMPERATURE CABINETS

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The effect of environmental variation upon insect behavior has been evaluated in the past by utilizing specially designed cyclic temperature cabinets. These cabinets are programmed to produce daily fluctuations in temperature which simulate specified climatic occurrences common to the apparent geographical range of the insect in question.

These environmental manipulations make possible the continuous, close observation of study material within the laboratory and consequent discovery of biological phenomena that might be easily overlooked in the field. For example, simulated daily cycles demonstrated a good correlation between environmental conditions and the number of progeny produced by the oriental fruit fly, Dacus dorsalis Hendel, (Flitters and Messenger 1953). In other cases, cyclic cabinets may be used to control photoperiods as well as temperature and humidity oscillations during diapause studies of insects exhibiting multi-voltine life cycles.

Basically the production or reproduction of a particular climatic environment for studies of terrestrial insects involves controlled oscillations of temperature, light, and humidity. A suitable cabinet should produce a wide range of combinations of these three variables, retain a relatively simple electronic design, and be inexpensive to build. The control system for each variable should work independently from control systems for other variables, thus enabling the production of any set of environmental conditions. Numerous cabinets have been developed with a control system for a single environmental factor and a few commercially available cabinets control temperature, humidity, and light simultaneously.

Designs for the production of daily cycles of temperature have been incorporated into household refrigerators equipped with heating elements and air circulation systems (White and DeBach 1960), into constant temperature cabinets (essentially the same as the household refrigerator design), and into walk-in coolers (Flitters and Messenger 1953). The control systems involve a mechanical or electronic device that provides continuous adjustment of a thermostimulator throughout the period of operation. These devices are basically of the same design: a one-revolution-per-day or week motor controls the daily cycle. Connected to this motor is either a cam (for irregular cycles), a variable length lever (for relatively homogeneous cycles), or an electronic plate (temperature cycles are controlled by a printed circuit of any design). From these discs, the temperature program is transmitted either by mechanical or electrical follow-up to the thermostimulator.

Each system has its advantages and disadvantages. The printed circuit board design of Munger (1944) is expensive from the standpoint of
Fig. 1. Constant temperature cabinet with cyclic control equipment.
initial cost of a hygrothermograph and occupies some of the available cabinet space because all control mechanisms are internal. However, Munger’s design allows for weekly heterogeneous cycles. The cam and follow-arm design presented by Flitters and Messenger (1953), Flitters, Messenger, and Husman (1956), Stone (1939), White and DeBach (1960), and Wishart (1940) involve the construction of suitable cams for each program desired, as well as a rather delicate follow-arm linkage system. However, this system will provide fluctuations of almost any design during a 24-hour cycle. The extended lever system of Howe (1956) is reportedly difficult to regulate (White and DeBach 1960), but is less delicate and eliminates the use of individual program cams. Through the elimination of cams, however, only relatively homogeneous cycles are produced. Pitman and Ryan (1962) improved upon Howe’s design by replacing the extended lever, a slotted arm, with a disc in which holes were drilled at progressively greater intervals from the center to receive the push-pull rod, thus enabling exact duplication of previous settings, and a fine adjustment by including a telescoping follow-arm. Periods of constant temperature in the temperature cycle were then introduced by including a time switch in the power supply to the clock motor.

The following cabinet was designed to produce a low cost environmental chamber capable of maintaining either synchronous or independent fluctuations of temperature, light, and humidity. It is capable of producing cyclic or constant temperatures, cyclic (during the temperature cycle only) or constant relative humidities, and cyclic or constant light of different intensities.

CABINET CONSTRUCTION

A constant temperature cabinet (No. 3553 Ambi-Lo, manufactured by Labline, Inc., Chicago, Illinois) with a United Electric thermoregulator (standard equipment on Ambi-Lo cabinets) provides the basic refrigeration-heating unit (Fig. 1).

A 24-hour time switch revolves a 7½-inch circular steel plate, described by Pitman and Ryan (1962). The plate is attached to the tapered shaft of the time switch motor by a left-hand threaded nut. The adjustable follow-arm is attached to the steel plate by a brass pin inserted through any one of the program holes. The head of this brass pin is sufficiently narrow to allow clearance of other moving parts throughout its rotation (Fig. 2 and 3).

The rack and pinion gear attachment to the thermoregulator, designed by Pitman and Ryan (1962), is replaced by a circular gear system which enables use of the United Electric thermoregulator. The adjustment knob of the thermoregulator is replaced with a 1-inch circular gear. Some difficulty was encountered in aligning the gear box with the thermoregulator gear, because the regulation shaft travels in a lateral direction during adjustment of temperatures. To compensate for this movement, and thereby provide for continuous gear connections, a ¼-inch wide gear was fastened to the thermoregulator shaft to provide sufficient gear width. The gear box, mounted on a pivot screw, may be disengaged from the thermoregulator for easy adjustment of the desired initial cabinet temperature.

Duration and intensity of light within the cabinet is controlled by a series of three Microswitches connected to one fluorescent tube and two
incandescent bulbs, respectively, operated by three cams driven by the time switch motor (Fig. 2 and 4). The control cams are connected to the motor through a series of extension gears (ratio 1:1) and mounted forward of the temperature program disc to allow easy access for adjustment of the cams. Each light is programmed by the shape and angular location of its cam throughout a 24-hour cycle. A set screw in the collar of each cam secures the cam to the cam shaft (Fig. 5). The fluorescent tube is fastened to a sliding tray and incandescent bulbs are mounted on the cabinet wall directly beneath the coil defrosting drain pan inside the cabinet (Fig. 6). A water drainage tube is connected to a hole in the bottom of the defrosting pan to expel excess defrosting water.
Fig. 3. Detail of temperature-program-plate attachment to 24-hour clock motor.

The humidity control system consists of a humidistat, two DeVilbiss hand atomizers operated by compressed air, and an air supply control valve (Fig. 4). The humidistat is constructed from parts of an old hygrometer, and functions as an electrical switch operated by the percent relative humidity surrounding the hair element (Fig. 7). It closes two solenoid circuits which control the flow of compressed air to the atomizers. The excessive arcing that would result from a 110-volt alternating current through the mercury switch on the humidistat is eliminated by a 6-volt direct current circuit. The 6-v d-c circuit is converted to a-c by a d-c-to-a-c relay (Fig. 4) which controls the operation of two self-canceling 110-v a-c solenoids. An air valve (aircraft-type oil valve) connected to the atomizers is opened and closed by the solenoids. Microswitches connected to the solenoids open the individual solenoid circuit as soon as each solenoid is closed and thereby prevent over-heating from a continuous current flow through the solenoid coil. Operation is as follows: reduction of percent relative humidity closes the mercury switch and opens the air supply to the atomizers; when the percent relative humidity increases to the desired level (set on the humidistat adjustment knob), the mercury switch opens and the air supply is closed.

A window located in the cabinet door eliminates the need to open the cabinet door during a cycle (Fig. 6). Three panes of glass, 1 inch apart, provide sufficient insulation, and a sponge rubber gasket around the viewing door eliminates external light from the cabinet.

Each cabinet component may be manually operated by one or a combination of the six switches on the control box on the top of the cabinet (Fig. 6). Three fuses are included within the cabinet circuits.
Fig. 4. Wiring diagram for cyclic conversion equipment.
Homogeneous daily temperature fluctuations ranging from 19 to 88 F are produced by connecting the thermoregulator follow-arm to the appropriate program hole in the temperature program disc (Fig. 8). The 19 program holes, each located ⅔ inch further from the disc center than the preceding hole, produce temperature ranges of 19, 20, 22, 24, 26, 30, 34, 37, 38, 42, 45, 52, 53, 56, 60, 66, 69, 74, and 88 F. The temperature curves conform with the constant temperature stability of ± 1 F at any point along the curve.

Percent relative humidity varies directly with the temperature in the closed cabinet without use of the humidity control system (Fig. 8). The frosting and defrosting of the refrigeration coils in the cabinet during a temperature cycle causes this inverse relative humidity-temperature relationship. The humidity control system produces a fairly constant relative humidity during temperature cycles, depending on the degrees of temperature fluctuation and/or the percent relative humidity selected to be maintained throughout the cycle (Fig. 9). As the temperature fluctuations and selected percent constant relative humidity are increased, the stability of the relative humidity is decreased.

Duration and intensity of light have no apparent effect on either humidity or temperature during cabinet operation. Any time combination of the three light sources may be used by selecting an appropriate light cam for each light to control its operation. The intensity of the light may also be controlled by combinations of the lights and/or the wattage of the incandescent light bulbs or fluorescent tube types (e.g., black light, daylight, etc.) selected.

**DISCUSSION**

The cyclic equipment added to the cabinet has no effect on the original constant temperature (± 1 F) produced by the cabinet during non-cyclic operation. The addition of time switches to individual components of the cyclic cabinet, therefore, produces timed periods of a constant environment at any point on the daily cycle. Constant temperature periods, during an uninterrupted temperature cycle, were demonstrated by Pitman and Ryan (1962), but the 24-hour cycle is extended by the summation of the time durations of the constant temperature periods.

The external location of all controls, with the exception of the adjustment for initial relative humidity, permits manual operation of the components and allows changes to be made in the automatic cycle while the
Fig. 6. Arrangement of water drainage trays, lighting system, and humidistat.
cabinet remains closed, thereby preventing disruption of the internal environmental conditions. The external atomizer water bottles can also be filled during extended periods of operation. Germicidal lights, substituted for normal bulbs, permit sterilization during any time interval throughout a cycle.

Fig. 7. Humidistat constructed from hygrograph parts.

Fig. 8. Percent relative humidity (below) varies directly with the temperature (above) in the closed cabinet without use of the humidity control system.
Fig. 9. Humidity control system maintains relatively constant humidities during temperature cycles.
The initial cost of a constant temperature cabinet is relatively high (approximately $500), but the cyclic controls are inexpensive. Many of the parts used in the control system were constructed from parts of scrap aircraft equipment, but they may be purchased from almost any machine shop. The total cost of producing this cabinet is low when compared to the commercially available cyclic-environment models.

**Summary**

Cyclic and constant temperature, light, and humidities are produced by the addition of conversion equipment to a constant temperature cabinet. Components of the conversion equipment include a 24-hour clock connected to a temperature program disc which continuously adjusts a thermoregulator by a mechanical linkage system, three light control switches operated by cams driven by a 24-hour clock, and a humidity control system.

The cabinet is capable of maintaining combinations of constant temperature, light, and humidity (each independent of the intensity of the other); synchronous fluctuations of temperature, light, and humidity; and independent fluctuations of temperature and light during which humidity can be held at a constant level or be allowed to fluctuate with the temperature.

**Literature Cited**


