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X BIOCLIMATIC CABINETS USED IN STUDIES ON
THE MEXICAN FRUIT FLY AND THE PINK BOLLWORM X

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Studies making use of especially designed cabinets to determine the effect of climatic conditions on the Mexican fruit fly (Anastrepha ludens (Loew)) and the pink bollworm (Pectinophora gossypiella (Saund.)) were undertaken at Brownsville, Tex., at the conclusion of similar studies on several fruit flies in Hawaii (Christenson 2, Flitters and Messenger 3, and Messenger and Flitters 5). These studies are concerned with determining the ability of the insects to develop and reproduce under various conditions of temperature, humidity, and light when adequate food, water, and acceptable ovipositional substrate are in constant supply. It is realized, however, that other physical and biotic factors may influence populations and affect activity and reproductivity of adults, since a species may not inhabit an ecological area that climatically and geographically appears to be most suited to its requirements.

A number of individuals and agencies have participated in the development of bioclimatic cabinets. Stone (8) devised an instrument for regulating fluctuating temperatures, and carried on bioclimatic studies of the Mexican fruit fly with such equipment in Mexico City. Munger (7) devised another instrument to accomplish the same purpose. In preparation for the studies in Hawaii, specifications for bioclimatic cabinets were drawn up by Department of Agriculture officials in consultation with numerous government and industrial refrigeration engineers. The instruments used to control cabinet performance have been described by Camp (1). The studies conducted in Hawaii established the suitability of this equipment and showed it to be efficient, reliable, and relatively free of operational difficulty.

In 1954 Mexican fruit flies were discovered at several points in northwestern Mexico near Tijuana, within a half-mile of the international boundary, and a single specimen was found in southern California near the border (Harper 4). These discoveries created an emergency need for expansion of the Mexican fruit fly program being conducted at Mexico City, and the bioclimatic-cabinet studies were initiated at the Pink Bollworm Research Center in November of that year. Experiments are also being conducted to ascertain the length of diapause or hibernation, rate of emergence, and mortality of the pink bollworm in normally infested cotton bolls when exposed to conditions of climate and environment found in widely separated cotton-producing areas in the United States. The abilities of introduced parasites and predators of the pink bollworm to establish themselves under such conditions are also planned for investigation.

In new cabinets set up at Brownsville several improvements were incorporated, the most important of which were the introduction of moisture in the form of steam, increased refrigeration capacity, variable heat input, and exterior access to the air-handling units, strip heaters, and blowers.

Cabinet Construction

The over-all dimensions of the cabinets (fig. 1), including the refrigeration equipment and control panel, are 9 feet 7 1/2 inches by 11 feet 8 inches by 7 feet 7 1/4 inches high. They are of sectional knockdown construction with 6 inches of fiber-glass insulation between 1/2-inch layers of plywood, and an additional lining of 15-pound vapor-proof building paper backing the outer plywood layer. The upper layer of the insulated floor is of 5/8-inch plywood. The exterior of the cabinet is painted with three coats of glossy white enamel, and the interior is lined with stainless steel with all seams sealed. The floor is provided with a single drain. The inner chamber is 6 feet square and 6 1/2 feet high.

One refrigerator-type door of construction similar to that of the walls, with stainless-steel inner surface and an opening approximately 2 feet 6 inches wide and 5 feet 9 inches high, opens outward into an anteroom. The anteroom measures 4 feet square, inside dimensions, and is of the same height and construction as the main room. It is equipped with an outer, heavy refrigerator door, similar to that used in the inner chamber but without the stainless-steel lining.

Opposite the door are two windows providing a total viewing surface of 15 square feet. Each window consists of three noncondensing Thermopanes 1/4 inch apart with the space between evacuated.

Two 250-watt infrared and two 15-watt ultraviolet lamps are installed on the wall near the ceiling. The infrared lights are adjustable so that they can be pointed in any desired direction. The starter and ballast for the ultraviolet lights are on top of the exterior of the cabinet. There is also a time clock outside the cabinet to give any desired operation of the lights per 24-hour period. A weatherproof socket for a standard light bulb is installed near the ceiling in one corner of the room and a weatherproof plug-in socket near the floor.

Mounted on the wall of each cabinet is an aspirator box of stainless steel which contains a small blower that draws air over a thermocouple and a humidity sensing element.

Air-Conditioning Equipment

The refrigeration compressor is powered by a 10-horsepower, two-speed motor, 1450 and 725 r.p.m. Monochlorodifluoromethane is used as the refrigerant. This compressor has automatic capacity unloading, permitting from one to four of its cylinders to operate, depending upon the load. It is provided with water-cooled cylinder heads to prevent overheating when operating at low suction pressures.

An evaporative condenser is suspended above the compressor unit from angle iron to provide the necessary refrigerant-condensing capacity. A sump tank is located below the coil to retain cooling water for recycling. Constant bleed-off of water prevents high concentration of minerals left from evaporation of the water. A float valve provides the necessary make-up water. To conserve the water, the supply through this valve is first taken through the compressor water-cooled heads, and any additional water for the compressor heads is drawn from the condenser sump. After it has circulated through the compressor heads, the cooling water is returned to the sump. A Kramer receiver large enough to store the entire charge of refrigerant is installed beneath the evaporative condenser.

In one wall of the cabinet are two air-handling units, mounted side by side with an insulated partition between them. Each is equipped with a large expansion coil having copper tubes and aluminum fins with 1/4-inch spacing, and over each unit are a 1/2-horsepower, 3-phase motor driving a squirrel-cage blower and three finned strip heaters having a total capacity of 8600 watts for air reheat.

Each coil is divided into three sections, each provided with an expansion valve so that there are three refrigerant circuits. Two circuits each has one-fifth and one circuit has three-fifths of the total refrigerating surface. By various combinations of these circuits it is possible to obtain increments of refrigeration in fifths of the total capacity of the coil. The first two refrigeration circuits are controlled by thermostatic expansion valves of 1-ton capacity, and the third circuit by a valve of 3-ton capacity.

Grease connections extend through the top of the housing to facilitate servicing from the outside. Beneath the refrigeration coils of each unit is a line to a floor drain.

On top of the housing for the air-handling units is a variable transformer (fig. 2) that controls the input to the heaters within.

The two air-handling units are enclosed in an insulated cabinet of construction similar to that of the main room. Each unit is provided with a separate access panel for readily servicing, and outside air intakes with adjustable dampers.

The two supply registers are adjustable so that the volume and direction of the circulating air may be controlled. Both the supply register and the return air grille are cadmium-plated to prevent rusting.

A 400-watt, copper-coated, cable-type electric heater is installed just below the refrigerant coil of each air-handling unit. The heat rises by convection and melts any ice or frost that has accumulated on the coil.

In the air duct of each unit an auxiliary 9-watt propeller fan is installed between the blower and the supply register. These fans circulate air in a reverse direction to the usual flow immediately after the defrosting heater has been turned off and before the unit is returned to operation. This reverse flow dries the moisture off the defrosted coils and brings them to room temperature, thereby eliminating temperature fluctuation when the unit is put into operation.

Humidity is supplied to the cabinet by means of steam regulated by pneumatic modulating steam valves (fig. 3) and solenoid valves.

Control Equipment

A heavy sheet-metal panel for mounting control instruments and attendant relays and accessories is installed adjacent to the anteroom and facing the front of the cabinet. On this panel are two time-pattern transmitters and two circular chart controller-recorders, one each for temperature and humidity (fig. 5). These instruments operate on 115-volt, 60-cycle current and require compressed air at 30 p.s.i. On the rear of the panel are six pneumatic-electric relay switches for controlling solenoid valves in the air-conditioning system, a diverting air relay and a 6:1 pneumatic air relay for controlling the compressor capacity, and a diverting air relay for controlling the opening of a modulating steam valve, as well as the accessory air pipelines, air-reducer valves and drip wells, and electrical connections.

Two 5-horsepower air compressors, one of them used as an auxiliary, supply air for the instruments and controls. A calcium chloride drier is located in the cabinet air-supply line.

The operation and the interrelationships between these control instruments are described in the section on Control Sequence.

At the side of the main panel is the electric panel (fig. 4) housed in a heavy metal cabinet with lock door. On this electric panel are fuse blocks, a two-speed magnetic starter for the compressor, a time clock for the air-conditioning unit cycle change, relays, and an interval timer for operating the refrigeration solenoid-valve controls. At the bottom are two timer-delay relays to control the blowers on cycling of units, two blower magnetic starters, an evaporative condenser magnetic starter, and a defrost timer. On the forward end of the panel, so as to be viewed from the front of the cabinet, are indicator lights that show which air-handling unit is in operation, how many refrigeration circuits are on, and when moisture is being introduced into the cabinet. Below these lights are switches to control the cycling of the units, operation of the defrost coil, and an on-off switch for the compressor. An additional safety switch to control the operation of the compressor is mounted on the panel. Above the panel is a Modutrol motor with four mercury switches to control operation of the refrigerant solenoid valves.

Control Sequence

One time-pattern transmitter, located on the control panel, has an arm which follows the curvature of a cam shaped to give the desired temperature to be maintained in the cabinet. This transmitter produces an air signal ranging from 2 to 14 p.s.i. over the range of the instrument, which is from -50° to $+150^{\circ}$ F. This signal is passed to the temperature controller-recorder installed above it.

If the temperature in the cabinet is below that desired, the air-pressure signal is built up by the recorder and is passed through a pneumatic motor to the variable transformer, which passes current to the electric air heaters to bring the conditions back to the control point. If the cabinet is warmer than indicated by the index on the instrument dial, the transmitted-air signal decreases, and when it falls below 6 p.s.i. refrigeration is turned on. The temperature can be raised or lowered as much as 40° F. in 60 minutes.

A 6:1 pneumatic relay is provided in the refrigeration-control air line to transmit air to the compressor-capacity-control device. As the output-air signals from the controller-recorders drop, the air pressure of this pneumatic relay also drops, giving a lower pressure to the capacity-control device to bring more cylinders into operation.

Since the compressor has this control providing for four steps of capacity by cylinder loading, as well as a control for operation at two speeds, and since five steps of capacity are provided by selection of the refrigeration-coil areas, it may be seen that by various combinations refrigeration capacity in forty steps may be obtained.

A time-pattern transmitter controls humidity in the same manner as that for temperature. This instrument passes a signal corresponding to any desired humidity. As the follower arm on the cam cannot climb a gradient of more than 70 percent and natural humidity patterns often present greater rises, the linkage has been changed to give a full range of signals using only the outer third of the regular cam. This signal is transmitted to a humidity controller-recorder directly above it. A humidity-sensing element in the aspirator box within the bioclimatic cabinet measures the relative humidity therein and transmits it to the control panel. This element, an electric hygrometer, is accurate to within $\pm 2^{\circ}\text{F.}$ of dew point through a range of 9 to 95 percent.

Should the humidity be below that desired, the air signal from the humidity controller will build up. This air signal is then transmitted to a pneumatic-electric relay, which makes contact at 13.5 p.s.i. and operates the steam solenoid valve. Should the humidity be above that desired, the transmitted air signal decreases, and since this signal is interconnected with the air signal from the temperature controller-recorder through a diverting relay which transmits the lower output from either instrument, the refrigeration cycle is brought into operation exactly as for temperature control. Complete saturation is possible within a few minutes at temperatures lower than 100°F. , and the humidity can be lowered as much as 60 percent per hour.

A steam-control valve that modulates the quantity of vapor flowing through the steam solenoid is positioned by the transmitted air signals from the time-pattern transmitters.

A pneumatic-electric relay, connected into the air line from the temperature transmitter, controls the compressor speed. High speed is obtained when the temperature drops to 30°F. or below, and low speed when it rises to 49° .

Cycle Changing

To provide for alternate operation and defrosting of the two air-handling units, two time clocks are provided (fig. 6). The main control time clock alternates the operation from one air-handling unit to the other after it has been in operation for any selected period. These periods may extend from 1 to 12 hours. An electrical time-delay relay in the circuit to the blower prevents it from starting for approximately 10 seconds after each cycle change. This permits the refrigerant to chill the coil or the heaters to warm up before the blower starts, thereby eliminating undesired disturbances in chamber-air control due to delays in performance of these units.

The second time clock controls the operation of the defrost heaters and auxiliary fans. Approximately 15 minutes after a cycle change this

clock turns on the defrost heater of the unit that has just gone out of service, and after 1 hour it turns off the defrost heater and turns on the auxiliary fan to dry the coil and return it to room temperature. The auxiliary fan continues to operate until about 15 minutes after the next cycle change, when the defrost cable on the other unit is then turned on.

Summary

Especially designed cabinets are being used at Brownsville, Tex., to determine the effect of different climatic conditions on the Mexican fruit fly (Anastrepha ludens (Loew)) and the pink bollworm (Pectinophora gossypiella (Saund.)).

Each cabinet has outside dimensions of about 9 2/3 by 11 2/3 feet and 7 2/3 feet high, and consists of an inner chamber and an outer chamber, refrigeration equipment, and a control panel. The insulated walls are of sectional knockdown construction.

Temperature and humidity conditions are maintained by water-cooled compressors, electric strip heaters, and steam-injection nozzles activated by pneumatic-electric controllers, guided by cams that set the pattern of temperature and humidity to be simulated. Daylight illumination is provided by infrared and ultraviolet lamps, and the length of daylight is controlled by time clocks.

To provide automatic defrosting there are two sets of cooling and drying coils, operated by time clocks over intervals of 2 to 12 hours, one coil being defrosted and dried while the other is in operation.

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Equipment

The equipment listed below is used in the cabinets at Brownsville, but this does not imply endorsement of instruments from these manufacturers in preference to others.

Elektronik temperature controller-recorder, Model 152P13P-195-1101.

Time-pattern transmitters of temperature and relative humidity,
Model 802A3A-X-80.

Elektronik humidity controller, Model Y152P13H-195-11.

Electronic hygrometer, system and elements, Model Special--
Range 9 to 95 percent.

All from Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.

Variable transformer, Superior Powerstat, Model 1256. Superior
Electric Co., Bristol, Conn.

Refrigeration compressor, Model 5F40. Carrier Corp., Syracuse, N.Y.

Evaporative condenser, Model EC5. Kramer Trenton Co.,
Trenton, N. J.

Air compressor, Model 253-D5. Ingersoll-Rand, Buffalo, N. Y.

Air-conditioning unit. Model LT-1. Recold Refrigeration Engineering,
Los Angeles, Calif.

Figure 1.--A bioclimatic cabinet, showing--
(1) entrance door, (2) temperature and relative-
humidity transmitters, (3) temperature and
relative-humidity controller-recorders, (4)
electric control panel, and (5) refrigeration
compressor.

Figure 2.--Variable transformer, which controls the current input to the strip heaters.

Figure 3.--Modulating steam valve, which regulates the amount of steam entering the cabinet to control the relative humidity.

Figure 4.--Main electric panel, showing--

(1) Compressor unit fuse block	(11) Auxiliary reheat change-over relay
(2) Air-handling unit blower fuse block	(12) Change-over relay--refrigerant solenoid valves
(3) Evaporative-condenser fuse block	(13) Terminal block
(4) Control fuse block	(14) Time-delay relay for unit No. 2
(5) Heater fuse block	(15) Blower magnetic starter for unit No. 2
(6) Two-speed compressor motor starter	(16) Evaporative condenser starter
(7) Cycle-change time clock	(17) Defrost and auxiliary-fan time clock
(8) Change-over relay blower and heaters	(18) Time-delay relay for unit No. 1
(9) Impulse timer	(19) Blower magnetic starter for unit No. 1
(10) Compressor positive off safety switch	