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ELECTRIC HEATING OF HONEY BEE HIVES
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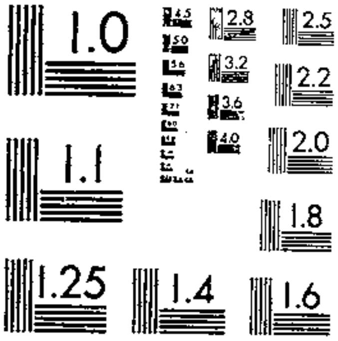
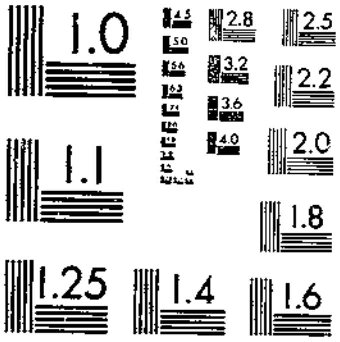


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Contents

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ELECTRIC HEATING OF HONEY BEE HIVES

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INTRODUCTION

In the 1940's some beekeepers reported that spring brood rearing could be increased through the use of electric hive heaters. Other beekeepers reported there was no benefit from heating hives. Most of these beneficial claims were made by operators who had not used proper testing procedures.

Peck (*5*)[1] and Butler (*1, 2*) showed that there was a temporary increase in brood rearing attributed to heating the hives. Most of these tests were made in the spring when the clusters of bees in the hives were small. No studies had been performed on wintering bees in the Langstroth hive.[2]

Many studies have been made on the protection of overwintering colonies by placing them in cellars, or by wrapping insulating material around the hives and keeping them outdoors. Wilson and Milum (*7*) used a limited number of thermocouples to study the effects of various treatments of the bee cluster. Their results did not show which treatment was the better one. Farrar (*3, 4*) states that a strong colony with ample stores of honey and pollen will live through a northern winter if placed in the shelter of a windbreak and exposed to the maximum amount of sunlight.

The results of our research are important to beekeepers who are concerned with overwintering bees and the possible supply of auxiliary heat. Other recent developments in certain environmental aspects of beekeeping stress the need for publishing these results at this time.

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[1] Italic numbers in parentheses refer to Literature Cited, p. 24.

[2] Trade names are used in this publication solely to provide specific information. Mention of a trade name does not constitute a guarantee or warranty by the U.S. Department of Agriculture and does not signify that the product is approved to the exclusion of other comparable products.

EXPERIMENTAL PROCEDURE

To determine the efficiency of hive heaters and their effects on wintering bees, studies were conducted at Madison, Wis., over a 5-year period. Electrically heated hives, insulated hives, and unprotected hives were studied. Five types of electrical heating were used. Data on temperatures in the hive, total energy consumed by the heaters, and the cycling of the heaters were obtained by use of recording instruments outside the hive so that the bees were not disturbed. Visual observations were made in the fall and spring. Cluster reaction to experimental treatment was determined by the temperature reading.

Description of Installation

All hives were three bodies high. Modified 12-frame Dadant hive bodies 6⅝ inches deep were used.

The center body of each hive had an auger hole, and the bottom entrance was reduced to a length of 1½ inches. Bees were placed in the specially wired bodies in the fall and were removed late in the spring. Type and duration of treatment and the number of hives that completed the test are shown in table 1. The bees were fed and manipulated as necessary. Sister queens were placed in

TABLE 1.—*Type and duration of hive treatment and number of hives tested*

Hive treatments; heating appliances and hive temperature (Fahrenheit) maintained	Duration of treatment	Hives tested
	Years	*Number*
Check hive	5	8
Wrapped hive	1	1
Packed hive	5	6
Heating tape—40°	5	8
35°	1	1
30°	3	6
25°	1	1
Heated box—55°	1	1
50°	1	1
45°	1	1
40°	2	2
35°	3	4
25°	2	3
Sechrist heater—40°	2	2
Porter heater—40°	1	1
Lyon heater—40°	2	2
Refrigerated check colony	2	2
Refrigerated packed colony	2	2

all hives in the fall to make the clusters as near equal as possible at the beginning of the experiment.

The wrapped hive had fiber-type building paper wrapped around it. The insulated hive, referred to in table 1 as the packed hive, was prepared as follows: Two inches of rockwool or fiberglass insulation was wrapped around the hive; an extra bottom board was placed upside down under the hive's bottom board, and 2 inches of insulation was placed between the two bottom boards; a piece of insulation was laid over the inner cover; building paper was then wrapped over all insulation to protect it from the weather. To hold the building paper in place, wood strips were nailed around the bottom of the hive and the cover placed on top of the hive. A wooden block with an auger hole drilled in it was nailed over the upper hive entrance to hold insulation in place and prevent bees chewing paper and insulation. After the first year, a vapor barrier paper was wrapped around the insulated hive before the insulation was applied to protect it from moisture generated by the bees and improve its efficiency (fig. 1).

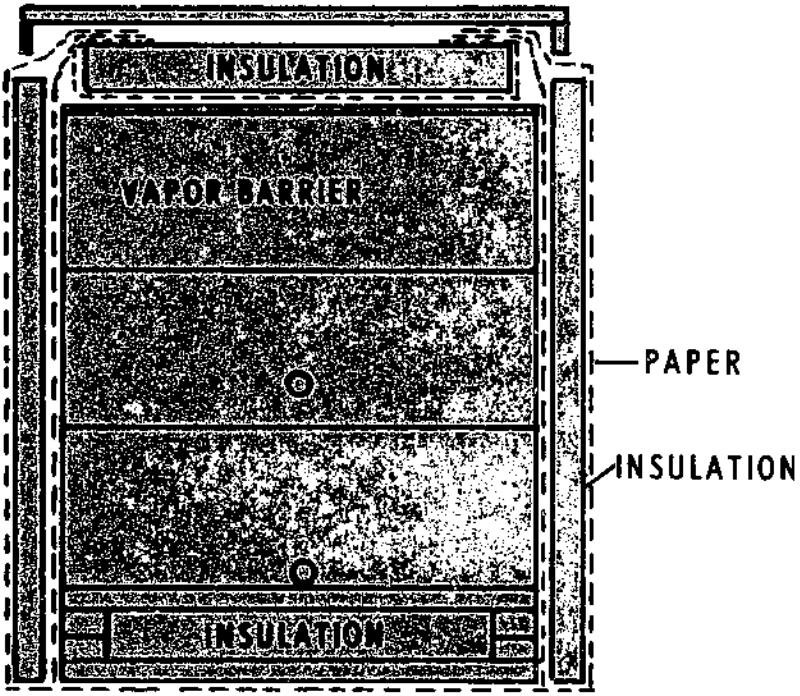

FIGURE 1.—Insulated (packed) colony showing where vapor barrier, insulation, and building paper were applied.

Heating the Hives

One method of heating was through the use of a 140-watt 20-foot plastic-covered heating tape wrapped around a hive (fig. 2). The thermostat was placed outside the hive on the east or north side midway between two wrappings of the heating tape. The hive then was insulated in the same manner as the packed hive. Different hives were heated at thermostat settings of 25°, 30°, 35°, and 40° F. (table 1).

FIGURE 2.—Hive showing placement of a 140-watt 20-foot heating tape and thermostat.

To simulate heated room conditions in which honey bees in hives are sometimes stored over winter, several hives were each enclosed in an insulated box that was heated by use of nichrome wires. Heating was controlled by a thermostat placed on top of the enclosed hive (fig. 3). The box enclosure was built large enough to provide a 6-inch space between it and the hive. Ventilation and a passage for bees were provided by a plastic tube. The temperatures in these hives were controlled by thermostats set at 25°, 35°, 40°, 45°, 50°, and 55° F. (table 1).

Three types of commercial hive heaters were used in the hives. The Lyon heater, a plate-type heater, was placed on the bottom board in the hive, and the thermostat was placed between the first and second hive bodies near the back of the hive.

The Porter heater was placed so that one of its heating units was positioned on each side of the bottom hive body in the space occupied by the outer combs and in lieu of them. The thermostat was placed between the heating units on the top bar of the bottom hive body.

The Sechrist heater was placed under the hive, and the thermostat was put under the screened passage of the bottom

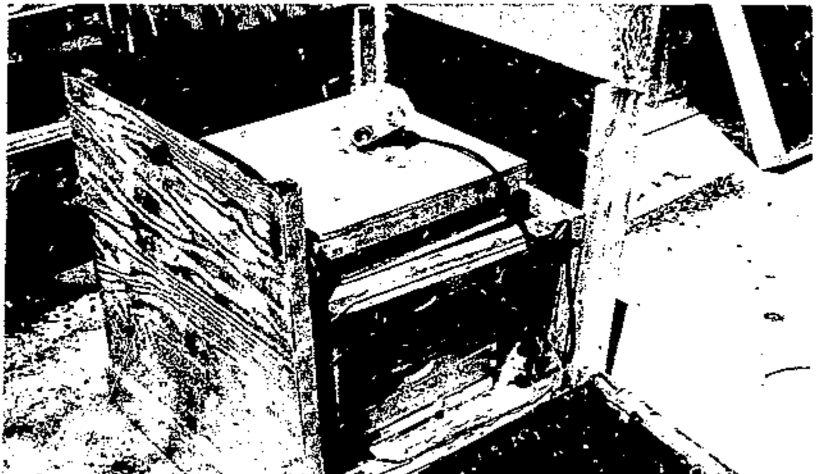

FIGURE 3.—Insulated box with nichrome wires that heated the enclosed hive. Heating was controlled by thermostat on top of hive.

board through which the air from the heater entered the hive (fig. 4). To improve heater the second year, a 2-inch fan was installed to blow air across the heater into the hive. Air intake to the heater was changed so that the effects of the modification made the heater a hot-air furnace with a continuously operating fan (fig. 5).

The use of commercial hive heaters (Lyons, Porter, and Sechrist) was discontinued after 2 years because these heaters could not be regulated satisfactorily and were less efficient than the heating tape. Insulated heated boxes were less efficient than the tape in heating hives, and it appeared that the enclosure affected the

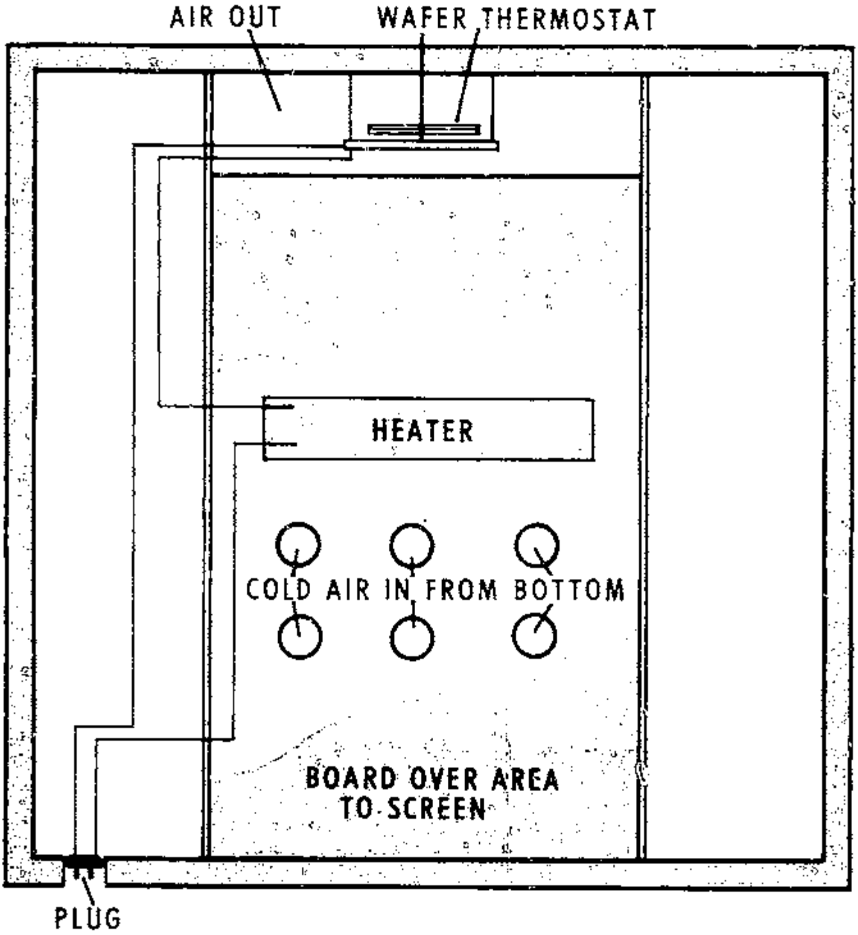

Figure 4.—Top view of original Sechrist heater installation showing wafer-type thermostat located under air outlet. Cold air entered through holes under heater.

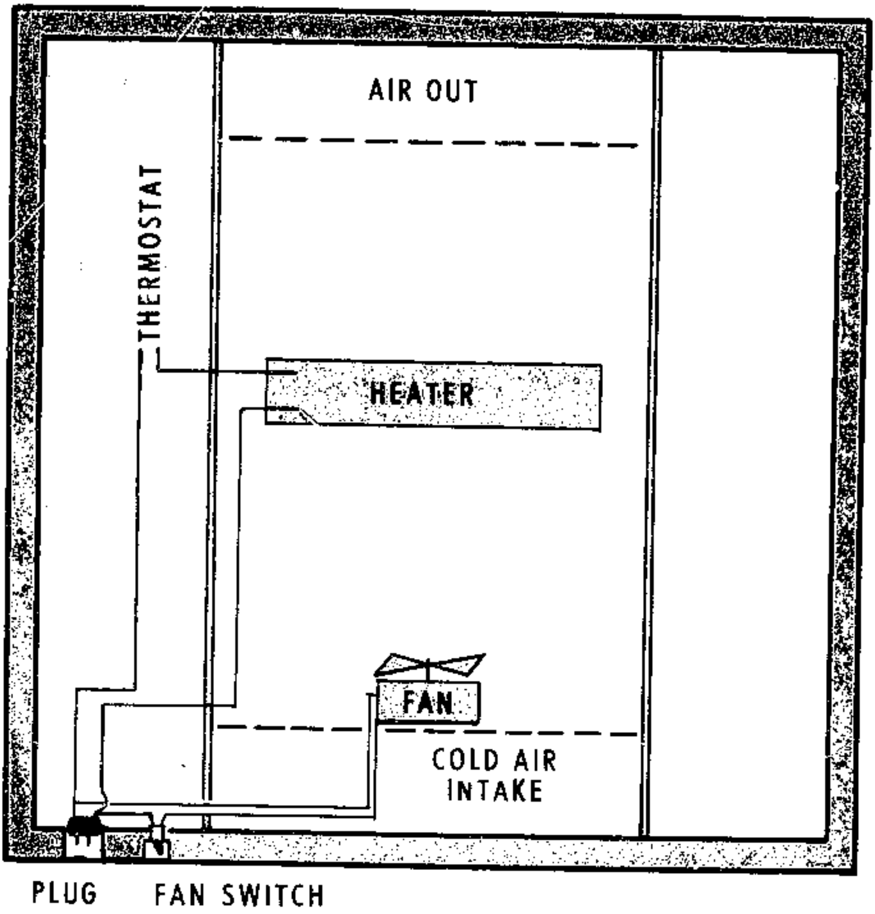

Figure 5.—Modified Sechrist heater installation. Top view showing where air enters and leaves the hive heating chamber.

results to a greater extent than it did the hive temperature. The entrance tube required bees to travel a long distance and tended to restrict their flying activity in that they were not able to discern the outside air temperature.

Instrumentation

Copper-constantan thermocouples were used to measure temperatures. These devices were placed in hive interspaces of all hive bodies. Beginning on the west side of the hive, eight thermocouples equally spaced vertically were placed in interspaces 1, 2, 3, 4, 5, 7, 8, and 9 (figs. 6, 7, and 8). In the odd-

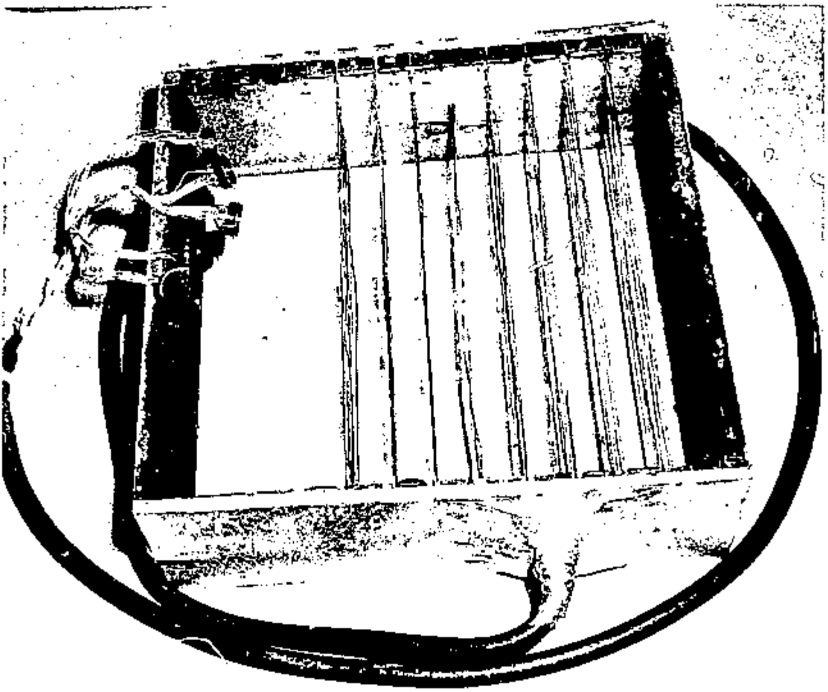

FIGURE 6.—Hive body wired with 80 thermocouples, looking down from rear side of body.

numbered interspaces, thermocouples were 5½ inches from the front of hive; those in even-numbered interspaces, 8½ inches from the front. Interspace 6 had 16 thermocouples evenly spaced from front to rear at middepth. A total of 80 thermocouples was installed in 9 of the 13 interspaces. This arrangement was used in top and center bodies of the prime test hives.

To keep the number of thermocouples to a minimum, some of the bodies were wired for 16 thermocouples—1 at midheight in each interspace and 8 in interspace 6. Hive bodies so wired were used as the bottom body of the hives and as components of some hives used for replication. A total of 1,600 to 2,000 thermocouples was used each year to measure temperature in 12 to 14 hives. Two special hive bodies were equipped with 192 thermocouples in the sixth interspace to determine the location of bees and brood in relation to temperature.

Thermocouples were connected in groups of 16 to plugs that were mounted in a panel in the instrument room (fig. 9).

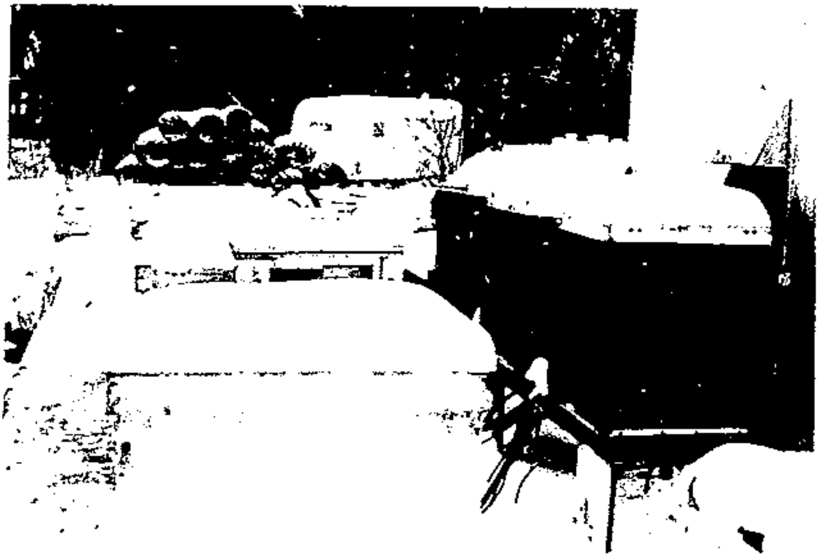

FIGURE 7.—Hive arrangement in the winter of 1951. Hive openings face south.

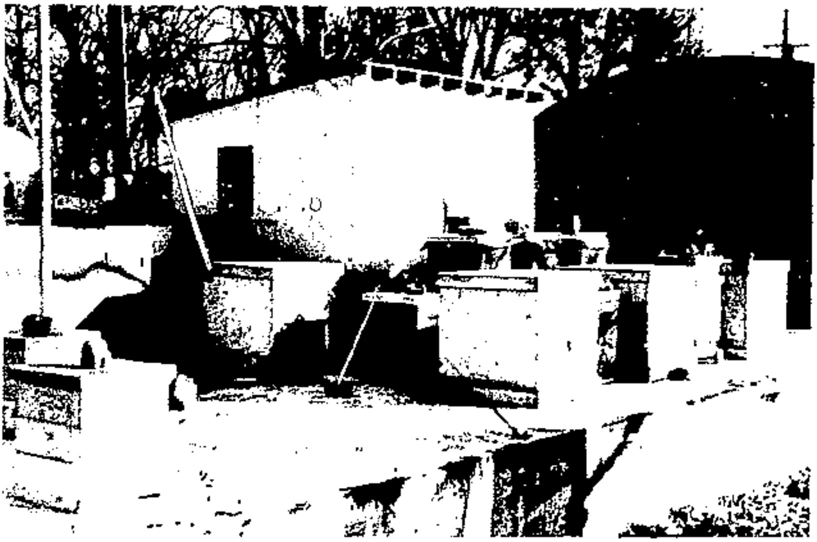

FIGURE 8.—Hive arrangement in the winter of 1952, showing instrument building. Hive openings face south.

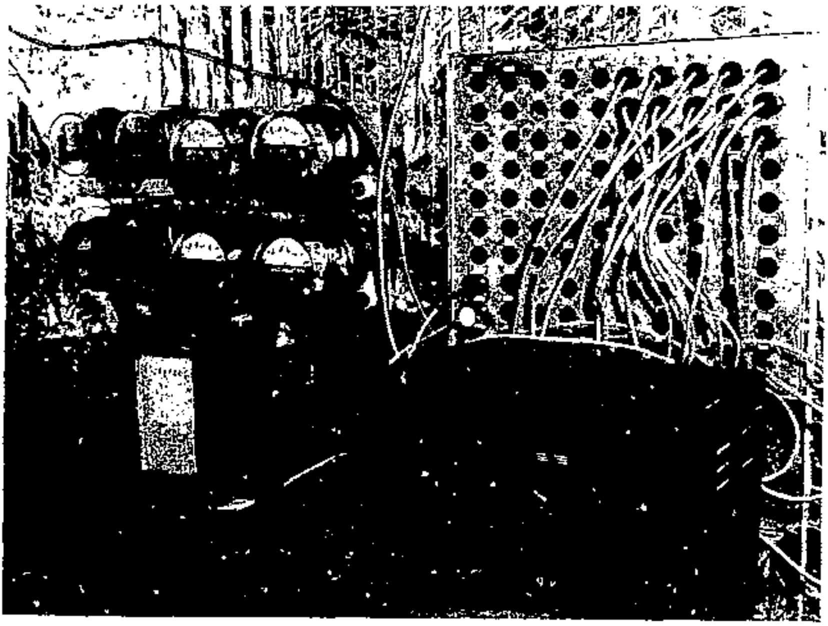

FIGURE 9.—Thermocouple board showing connections to multiswitching unit and watt-hour meters.

Temperature measurements were recorded by a Minneapolis-Honeywell 16-point self-balancing potentiometer. To facilitate the recording of temperatures, a 20-bank automatic mechanism designed by John G. Taylor (*6*) was placed between the panel and the recorder. This made it possible to record the temperatures at 320 thermocouples in sequence on a 16-point recorder. A time clock switched on the recorder at the desired times.

When power was off, a dot was made on the chart by a pen to mark the end of a reading. A thermocouple on every fifth plug was used to identify the plug number by printing a fixed (known) temperature. To identify the recorded data with the proper hive, a record was kept of the clock setting and of the position of plugs on the board, and the date was marked on the chart at least every other day. Complete records of settings were marked on chart when plugs were changed.

Periodically, the temperature of all thermocouples was recorded as fast as the machine would print, and this provided a reading every 7 to 12 seconds. This procedure gave a record of all hives on that date and at approximately the same time, while automatic recording would only cover 2 hives at a time. Thermocouples were installed to determine the efficiency of insulation and the accuracy of the heater thermostats.

A watt-hour meter was placed on each heater circuit to record the total energy consumed by the heater. A curve-drawing wattmeter was placed in the heater circuit to record the cycling and energy consumed by heater at various outside temperatures. Outside air temperatures were recorded by a thermograph in a weather station near the hives. All records were used to get a composite reaction of hives to heat and of the action of heaters during the winter season.

EXPERIMENTAL RESULTS

Performance of Hive Heaters

Tests were performed from early in December to late in March each year during the period 1949–55. Outside air temperatures during the tests are shown in table 2.

Table 2.—*Outside air temperature extremes, dates of occurrence, and monthly averages in winter during 5-year test*

Month	Maximum			Minimum			Monthly average
	Day of month	Year	Temperature	Day of month	Year	Temperature	
			°F.			°F.	°F.
December	3	1951	59	27	1950	−14	23.76
January	15	1953	53	29 and 30	1951	−20	19.74
February	15	1954	56	2	1951	−18	24.58
March	21	1953	72	2	1951	−7	29.92
Test period							24.5

The energy consumed by each kind of heater and the efficiency of the heater are shown in table 3. Consumption of energy varied from year to year, and it also varied among similar heating units. Degree-days are figured on the difference between the thermostat setting and the mean outdoor temperature for each day of the test season. Degree-days [3] for a 40° F. tape-heated hive for each year may be used to compare the severity of the year's outdoor air temperature.

Insulation efficiency, cluster size, and wind exposure were the causes of variations in performance among heating units. Some insulation was wetter than other insulation; this reduced the insulation value. All hives were close to each other; therefore, some received wind protection from adjacent ones. The instrument building provided some protection. The energy consumed by hive heaters was influenced by the hive insulation and the exposure of hive to prevailing wind.

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[3] Degree-day: A unit that represents one degree difference between thermostat setting and the day's average outdoor temperature.

TABLE 3.—*Summary of energy consumed by heaters and their efficiency*

Heater and thermostat setting—Fahrenheit	First year (11-28-49 to 4-21-50)		Second year (11-8-50 to 4-5-51)		Third year (11-19-51 to 4-7-52)		Fourth year (12-1-52 to 4-6-53)		Fifth year (11-9-53 to 4-2-54)	
	Energy consumed	Degree-days per kw.-hr.	Energy consumed	Degree-days per kw.-hr.	Energy consumed	Degree-days per kw.-hr.	Energy consumed	Degree-days per kw.-hr.	Energy consumed	Degree-days per kw.-hr.
	Kw.-hr.		*Kw.-hr.*		*Kw.-hr.*		*Kw.-hr.*		*Kw.-hr.*	
Tape: 25°	---	---	---	---	2	250	---	---	---	---
30°	---	---	---	---	3.9	225	0.3	2,067.7	1.7	38.7
	---	---	---	---	---	---	2.0	311.5	6.7	98.2
	---	---	---	---	---	---	1.0	623.0	---	---
35°	---	---	---	---	5	278	---	---	---	---
40°	29	68.9	43	53.7	18	110	11.5	143.8	12.8	132.4
	---	---	---	---	---	---	11.3	146.4	16.2	104.6
	---	---	---	---	---	---	8.0	206.8	---	---
Nichrome wires: 25°	---	---	17.4	43.5	5.0	100	---	---	---	---
	---	---	---	---	6.0	83.7	---	---	---	---
35°	50.9	25.8	54.8	31.8	36.3	37.2	---	---	---	---
	---	---	---	---	29.7	46.7	---	---	---	---
40°	91.6	21.8	68.0	34.0	---	---	---	---	---	---
45°	130.0	20.5	---	---	---	---	---	---	---	---
50°	147	22.9	---	---	---	---	---	---	---	---
55°	---	---	168.8	23.7	---	---	---	---	---	---
Sechrist: 40°	106.0	18.8	61.5	37.6	---	---	---	---	---	---
Porter: 40°	42.5	47.0	14.8	[1] 15.6	---	---	---	---	---	---
Lyon: 40°	22.5	88.7	(1)	(1)	---	---	---	---	---	---
Degree-days at 40°	1,997		2,310		1,974		1,654		1,695	

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[1] Bees on thermostat.

The location of the cluster in the hive affected the thermostats that were located in the hive. For example, the Lyon heater used 22 kilowatt-hours the first year and none the second year as the cluster was around the thermostat all season. Energy consumption of the Porter heater was also affected by having the thermostat in the hive. The tape and box heaters were affected slightly by colony size, but the effectiveness of the insulation and the exposure to prevailing wind influenced the consumption more.

Locating the thermostat between the insulation and the hive body gave the desired temperature control and was used for all heaters the last 2 years of the experiment. The box units were dropped because it appeared that the enclosure affected the results more than the temperature. The tubes made a long distance for the bees to travel and tended to restrict their flying because they could not sense the outside air temperature.

The Sechrist heater was modified both years to help improve its operating efficiency. The first year the thermostat was moved from a cold location to a place in the heated air stream. The wafer-typé thermostat had a 13° F. differential, and the amount of energy used was erratic at all outside air temperatures. This erratic operation was due to (1) the amount of air flowing across heater strip up into the hive was determined by the wind direction and velocity, (2) and the poor sensitivity of the thermostat. The second year a more sensitive thermostat was used and a 2-inch tube cooling fan was placed to blow air across the heating element into the hive. The outside air holes were closed, and a hole in the bottom board near the front entrance was used for cold air intake to heater (fig. 2).

The Porter heaters had their thermostats located on top of the center honeycombs. Each unit of the heater was rated at 60 watts, making the total capacity of a heater 120 watts. The heater did not soften the combs next to it, nor did it add heat to the bottom hive body. Maximum air temperature on top of the heater was 80° F., and the maximum recorded on the side next to the combs was 60°. The temperature in the top two bodies was above 40°, even without bees. The bees died in February of the first year for an unknown reason. After that, the heater was operated to determine its characteristics without bees in the hive. Later on, the insulation on the hive was removed to determine heat requirements for an uninsulated hive without bees. Heat requirements under these three conditions are shown in figure 10.

Figure 11 shows the distribution of heat produced by a Porter heater in a three-body hive, as affected by bees and insulation. The

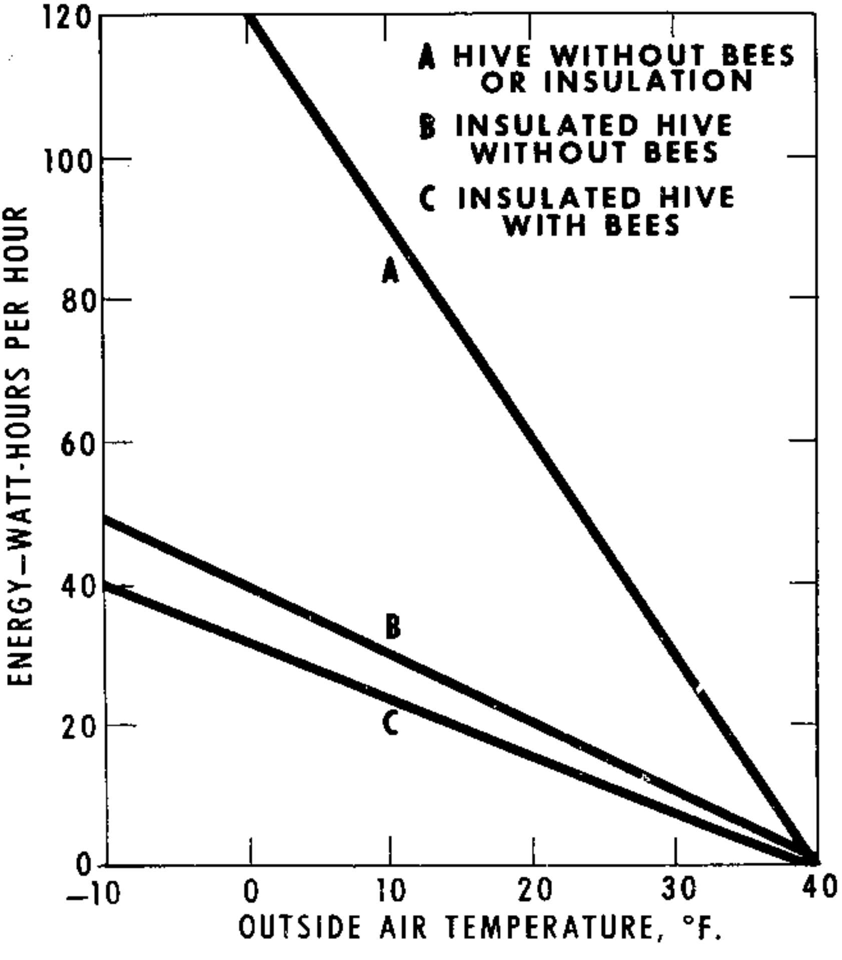

FIGURE 10.—Energy consumed by a Porter heater at various outside air temperatures under stated hive conditions.

efficiency of the Porter heater compared favorably with other heaters used in the experiment. The high number of degree-days per kilowatt-hour for the 1950–51 season was caused by bees being clustered on or near the thermostat all season. Because the thermostat was influenced more by the bees than by the weather, the Porter heater was omitted from further hive-heating experiments.

The Lyon heater was a 60-watt plate-type heater, and its thermostat was located in the same position as that for the Porter heater. A maximum temperature of 108° F. was recorded on the surface of the Lyon heater. Cluster location was influenced by the heater both years. The heater caused the bees to locate low in hive. This

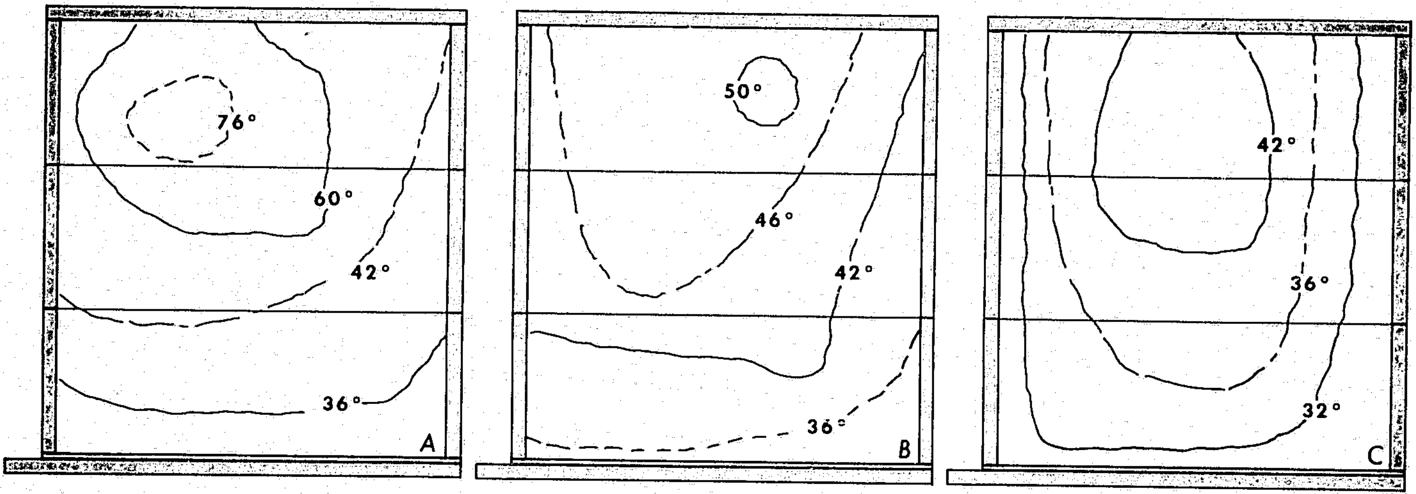

Figure 11.—Distribution of heat produced by a Porter heater in: *A*, an insulated hive with bees at noon on December 22, 1949, when the outside air temperature was 18° F.; *B*, an insulated hive without bees at 5 p.m., March 9, 1950, when the outside air temperature was 21°; and *C*, a hive without bees or insulation at 7 a.m., March 29, 1950, when the outside air temperature was 22°.

in turn influenced heater operation. During the second year, the heater consumed practically no energy because the thermostat was covered by the cluster almost all season. The heater had enough capacity to maintain the temperature setting when the outside temperature was as low as − 15°. The Lyon heater was discontinued for the reasons that the Porter heater was discontinued.

Hives enclosed by insulated boxes had the interspace heated to determine the effect of various temperature settings on bee wintering. The cluster was not affected much by outside air temperature in this method of heating because the air was heated to some degree in the entrance tubes before it entered the hive. Heat distribution around the hive was good. The top of the box was 5° to 8° F. warmer than the bottom, and there was about a 3-degree temperature difference between the hive's outside surface and the box's inside surface. Tests with insulated boxes provided much useful information as to the size of heater required to maintain a given temperature and the type of thermostat that would best control the heat.

A curve-drawing wattmeter was used to determine the cycling time of the heaters and that they had enough capacity to maintain the hive temperature at thermostat setting. The heat required to maintain hive temperature at stated thermostat settings for various outside temperatures is shown in figure 12.

The box heater from which the data for figure 12 were obtained should be approximately 50 percent larger than was used to heat the hive in prolonged cold periods. However, if the heater is too large, the thermostat cannot keep up with the change in temperature, which results in the hive getting hotter than the thermostat setting before heater is shut off. To maintain hive temperature near to that for which the thermostat is set, the thermostat must be highly sensitive and have a narrow differential. Household-type thermostats are not suitable because they do not respond rapidly enough to temperature changes. Except for the entrance response, bees in boxed hives responded no differently at the same temperature than those in thermotape-heated hives. However, the long tube at hive entrances probably restricted the bees flying on warm days, an activity that permits them to clean the hive. This restriction makes it impossible to predict the bee response to temperature; therefore, boxed hives were not used the last 2 years of the experiment.

Heating tape was found to be an efficient method of heating. Because the tape is placed around the outside of the hive, installation was simple, and its use caused a minimum of disturbance to

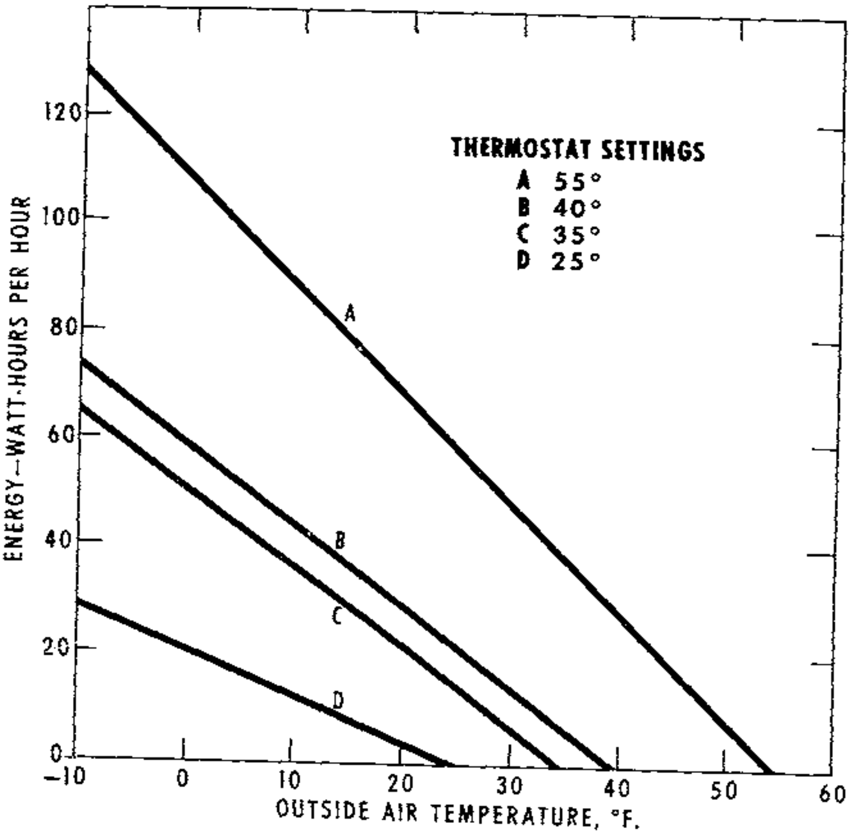

FIGURE 12.—Energy consumed in 1951 by a box heater with thermostat set at various stated temperatures.

the bees. During the last 2 years of the experiment, the heating tape was the only method of heating used, and the number of thermostat temperature settings was reduced. The result was an increase in the number of replications.

The high efficiency of heating tapes is primarily due to the fact that the whole hive was heated and not just the air. The large heated mass helped to maintain warm conditions during the short periods of low temperature. To maintain a uniform or nearly uniform temperature from bottom to top of hive, the spacing between tapes had to be less at the bottom than at the top. Placement of the thermostat against the hive under the insulation prevented the cluster affecting the operation of the heater.

Heating tapes operated uniformly throughout the outside temperature range, and their 140-watt capacity was enough to heat the hives at all temperature conditions encountered during the experiment. A difficulty in use of the tape occurred at sharp corners where the wire broke after a short period because of the stress during changes in temperature. Padding the corners eliminated this trouble. The operating temperature of the tape was low enough so that no scorching of hives or insulation occurred. The maximum temperature recorded under the tape was 102° F.

The type of heater and method of installation affected energy consumption. Figure 13 shows the energy consumed by various makes of heaters set at 40° F. during the 1949–50 test at stated outside air temperatures. Because of low air movement over the heater and an insensitive thermostat, the Sechrist heater operated very irregularly near the thermostat setting.

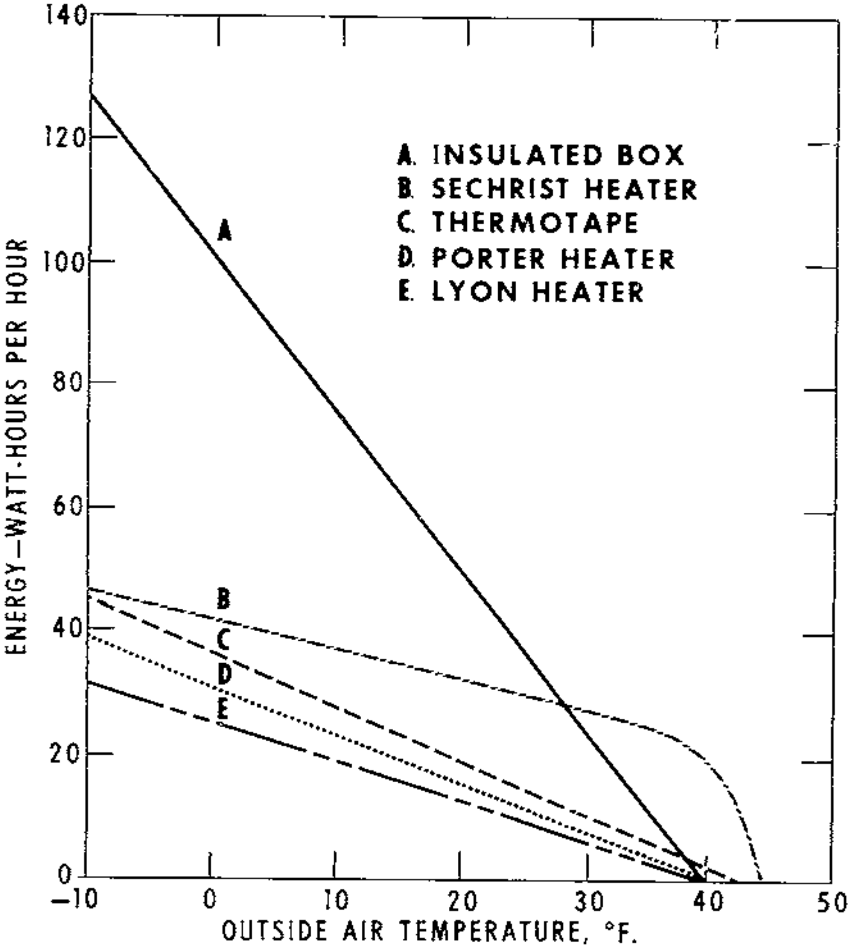

FIGURE 13.—Energy consumed for stated outdoor temperatures in 1949–50 by several makes of hive heaters set to operate at 40° F.

Bee Cluster Reaction to Treatment

Each hive treatment is discussed separately and compared with the check hive. Cluster movement was affected by solar radiation.

Wrapped Hives

Two hives, one wrapped in brown building paper, the other in black building paper, were tested during the first 2 years of the experiment. Color of paper did not cause any difference in hive temperature. The building paper caused the temperature outside the cluster to be about 2° F. higher than in the check hive. Building paper reduced air leakage through the hive and possibly would be desirable in locations where hives are exposed to winds of high velocity.

Packed Hives

After the vapor barrier was added, little of the insulation became wet, but the inner cover became very wet. Hive temperature outside the cluster averaged 7° F. warmer than in the check hive. Location and compactness of clusters changed less in packed hives than in the check hive when outside temperature was low, but they changed more in the packed hives than in the check when the outside temperature was above 30°. Temperature readings showed the cluster compactness in packed hives to be equal to that in tape-heated hives. Insulation caused the hive temperature to lag the outside air temperature by 6 to 8 hours. This was about three times longer than the length of lag in the check hive.

Tape-Heated Hives

The effects of four temperature settings—25°, 30°, 35°, and 40° F.—were tested. The 25° setting furnished insufficient heat to cause the hive to react differently than the packed hive. The 35° setting was dropped after 1 year because a 5° difference among settings was not enough to show a difference in the data. Therefore, the majority of the tapes were operated at 30° and 40°. Compactness of cluster among tape-heated hives differed but little because of thermostat settings. The tape-heated hives had much larger clusters or they were less compact than those in the check, or unheated, hives. This was most noticeable in what has been referred to as the insulating shell. Cluster size changed more with changes in outside air temperature in tape-heated hives than in the check or the packed hives. Heating the hives by conduction maintained a more uniform hive temperature than by other methods of heating.

Boxed Hives

Box temperatures during the experiment were maintained at

25°, 35°, 40°, 45°, 50°, and 55° F. The air temperature in boxed hives was closer to the thermostat setting than it was in hives heated by other methods. The cluster showed no change that could be attributed to entrance effect, sun's radiation, or change in outside air temperature. Therefore, bees did not fly out in warm days as they did from other hives. Bees did not form a definite cluster in the 55° box. The various temperature settings did not affect the cluster survival. A weak cluster was held over winter at 25° and another one at 35°. In the spring both clusters were as strong as those that had been rated good in the fall. Therefore, protection by heat does benefit weak clusters.

Lyon-Heated Hives

The Lyon heater was operated with a thermostat setting of 40° F. The thermostat was located in the hive, and its operation was influenced by the cluster location. For this reason, the operation of the Lyon heater was erratic because the cluster stayed on or near the thermostat. Compared with the other heaters, the Lyon heater had considerable effect on the shape and location of the cluster. Its erratic operation did not give a true picture of the effects of heat on the cluster during winter. The Lyon heater was abandoned after 2 years in favor of the tape heater.

Sechrist-Heated Hives

During the first year, the Sechrist heater was operated with natural air circulation with the result that it had less effect on the compactness of the cluster than any other heater. Although the cluster was located in the center of the hive, very little heat reached the cluster.

During the second year, a small fan was used to circulate the air from the heating unit. Temperature data showed that the continuous movement of air disturbed the bees. We concluded, therefore, that if heat were beneficial this heater would not be the one to use. Experimental use of the Sechrist heater was discontinued.

Porter-Heated Hives

This heater was operated at 40° F. and maintained good temperature above the bottom hive body. The cluster remained relatively low but had a normal shape throughout the season. It was located within the pattern of heat distribution for the Porter heater. The thermostat was located inside the hive and was affected by the bees and not the temperature of the hive.

A summary of cluster response to the various experimental treatments is shown in table 4.

TABLE 4.—*Summary of colony response to tests*

Hive treatment	Year	Fall condition [1]	Spring condition [1]	Weight loss	Date first brood [2]	Energy consumed
				Pounds		*Kw.-hr.*
Tape-heated hive—25° F	1951–52	2	4	38.9	Jan. 31	2
Tape-heated hive—30° F	1951–52	2	4	40.4	Jan. 31	3.9
Do	1952–53	2	2	--------	Mar. 9	.3
Do	1952–53	2	4	--------	Mar. 20	2.0
Do	1952–53	3	2	--------	All season	1
Do	1953–54	2	4	48	Feb. 3	1.7
Do	1953–54	2	4	40.5	Feb. 3	6.7
Tape-heated hive—40° F	1950–51	2	4	35.6	Mar. 5	43
Do	1951–52	2	2	28.4	Feb. 5	18
Do	1949–50	3	4	47.2	Jan. 17	29
Do	1952–53	2	4	--------	Mar. 17	11.5
Do	1952–53	3	2	--------	All season	11.3
Do	1952–53	1	2	--------	Feb. 12	8
Do	1953–54	2	4	40	Feb. 3	12.8
Do	1953–54	5	4	47	Feb. 3	16.2
Tape-heated hive—35° F	1951–52	2	5	55.1	All season	5
Packed hive	1949–50	4	6	63.5	Jan. 19	------
Do	1950–51	2	2	34.8	Jan. 22	------
Do	1951–52	2	4	38	Jan. 10	------
Do	1952–53	2	2	--------	Feb. 4	------
Do	1953–54	3	4	32.75	Feb. 10	------
Do	1953–54	2	5	42	Feb. 10	------
Check hive	1949–50	2	4	63.4	Jan. 4	------
Do	1949–50	2	6	69.1	Apr. 10	------
Do	1950–51	4	6	53.3	Mar. 5	------
Do	1950–51	2	4	72.42	Jan. 8	------
Do	1951–52	2	4	54.2	Feb. 11	------
Do	1952–53	2	2	--------	Feb. 4	------
Do	1953–54	2	4	52.5	Jan. 14	------
Do	1953–54	2	5	35.25	Mar. 18	------
Boxed hive—25° F	1950–51	3	5	46.8	Feb. 26	17.4
Do	1951–52	5	5	43.2	Feb. 11	5
Do	1951–52	1	5	47.5	Jan. 14	6
Boxed hive—35° F	1949–50	2	5	54.3	Feb. 7	50.9
Do	1950–51	2	5	39.9	Mar. 5	54.8
Do	1951–52	2	4	46.5	Feb. 11	36.3
Do	1951–52	4	5	29.1	Mar. 6	29.7
Boxed hive—40° F	1949–50	3	6	37	Jan. 27	91.6
Do	1950–51	2	4	45.3	Feb. 26	68
Boxed hive—45° F	1949–50	2	5	35.3	Mar. 13	130
Boxed hive—50° F	1949–50	2	4	59	Feb. 2	147.5
Boxed hive—55° F	1950–51	2	4	50.5	Feb. 26	168.8
Sechrist-heated hive—40° F	1949–50	4	4	44	Mar. 1	106
Do	1950–51	2	5	81.2	Feb. 26	61.5
Porter-heated hive—40° F	1950–51	2	4	75.6	Feb. 26	14.8
Lyon-heated hive—40° F	1949–50	3	4	56.4	Feb. 24	22.5
Do	1950–51	2	5	62.82	All season	------
Wrapped hive	1950–51	2	5	45.9	Mar. 19	------

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[1] Hives were inspected to determine cluster size and condition. A rating of 1 means the cluster had 30,000 bees and better reserves than clusters rated 2 through 6; rating of 2 means the cluster was 30,000 bees; 3, cluster was 25,000 bees; 4, 20,000 bees; 5, 15,000 bees; and 6, 10,000 bees.

[2] Date that the first brood-rearing temperature was reached in the cluster. "All season" means that brood temperature existed throughout the test period.

SUMMARY AND CONCLUSIONS

In 1940 claims for the advantages of electric hive heaters were being made without data. Therefore, studies were conducted at Madison, Wis., for 5 years to determine the effects of hive heaters on bees. Three commercial hive heaters were tested against unprotected hives and against protected hives without heat and against hives heated by heating tape.

All hives consisted of three modified Dadant hive bodies. All packed and heated hives were insulated on all sides with 2 inches of insulation. Hives were also placed in heated boxes to determine the effects of storing hives at various room temperatures. The use of commercial hive heaters was discontinued after 2 years because they were inefficient or had adverse effects on the cluster. The boxes and some temperature settings were discontinued during the experiment in order to have more replicas of other treatments.

Data on temperatures in the hive and the energy consumed by the heaters were obtained by remote recording instruments. A total of 1,600 to 2,000 thermocouples was used each year to measure temperature in 12 to 14 hives.

Electric heaters that heat by conduction and radiation were more efficient in maintaining honey bee clusters at a given temperature than heaters that heat by convection. Because of the small volume of air in hives, the thermotape was most efficient in heating the hives. Heating without the use of insulation is very expensive.

Five years of tests show that colonies of bees in good condition will winter at Madison, Wis., without packing or heating. Clusters respond to changes in air temperature according to the degree of their protection, but supplementary heat reduces this response. Colonies that had the entering air tempered by heat did not respond to outside temperatures. The temperature at which insulation or protection would be economical to the beekeeper was not determined.

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