HIVE TEMPERATURES FOR EACH HOUR OF A DAY.*

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INTRODUCTION.

Of the climatic factors in the environment of the honey-bee, temperature modifies their reactions more than any other factor. The well known clustering of bees during the winter and the period of normal brooding of honeybees are two distinct physiological conditions within the colony, brought about by the one environmental factor, temperature. The former condition has been the subject of a great deal of experimental work and has been worked out rather thoroughly. On the other hand, investigations on the latter condition have been more or less limited.

This study on the temperatures within the colony was carried on during the summer of 1926.

I wish to express my appreciation to Professor W. M. Barrows for his helpful suggestions and encouragement in many phases of the work; to Dr. E. F. Phillips, Cornell University, for loaning German beekeeping literature pertaining to hive temperatures, and to Mr. Morris Schlosberg, for his help in constructing the compound thermocouple.

REVIEW OF IMPORTANT PAPERS ON HIVE TEMPERATURES DURING SUMMER.

Francis Huber (1791) who was one of the early investigators on bee life, made observations on brooding temperatures. He stated that in hives rearing brood during the month of January he had obtained the temperature of 93 degrees F. He criticized the statement of Dubost, of Bourg-en-Bresse, that larvae could not hatch below 104 degrees F. Huber stated that the ordinary temperature of hives in summer was from 95 degrees to 97 degrees F. One particular observation was made when the outside temperature was 94 degrees F. At the same time in the most populous hive it did not rise above 99 degrees F.

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A. I. Root in 1899 made some observations on the proper temperature for brood rearing. He placed a self-registering thermometer in the center of the brood nest of a medium sized colony and found that the coolest temperature reached during the night period when the external temperature was below freezing was 92 degrees F. In stronger colonies he observed that the temperature registered 95 degrees F. on very cool nights. During a very hot day in August when the external temperature registered from 90 degrees to 95 degrees, he found that in a strong colony the highest point reached was 98 degrees F. In conclusion he stated that the temperatures most conducive for successful brood rearing within the hive were between 92 degrees and 98 degrees F.

Gates in 1914 carried on extensive studies on the temperature within the bee colony during the winter and summer periods. Gates reported some observations which were made in 1908. On March 12th, he opened a hive and found eggs less than 3 days old. At a corresponding time, the course of thermometer c, which was in the region of egg laying, changed; and the inverse relationship which existed during the winter period was no longer apparent. He stated that the trend of the thermometer c was slightly upward during the warmth of the day which corresponded somewhat with the warmth of the outside temperatures. He said that there was a transition from winter to summer (a broodless condition to a condition of normal brood rearing) covering a period of two weeks. In the middle of the brood nest during the summer period, there was no appreciable correlation between the brood temperatures and external temperatures. The hive temperature as a whole was independent of external temperatures, however, a few exceptions to this occurred. The temperature in the brood nest was remarkably constant, ranging from 93.2 degrees to 95 degrees F. The range of the oscillation showed the consistency of the temperature during the height of the season and the greater fluctuations in the spring and fall.

Brunnich in 1919 conducted some research work on colonies rearing brood. All of his observations were taken on weak colonies. Of 27 brood nest readings the temperature was 113.36 degrees F.; 17 were 104 degrees F.; and 7 were 105.4 degrees F. He said that brood did not tend to cool off the hive, but rather was a heat producer which could exist only in an environment

of about 98.6 degrees F. He stated that his observations were probably more or less inaccurate.

Armbruster in 1923 published an article on the temperatures within the bee colony. This work summarized the observations carried on by Lammert in 1894 and 1895 and those of Gates in 1914. He referred to Lammert's notes concerning a swarm of bees hived in a burlap sack within which a temperature of 100.4 degrees F. was obtained. After 8 days, the time when a first swarm possesses a good brood nest, normal temperatures of 95 degrees were resumed. Armbruster continued to describe Lammert's work, but in conclusion he stated that this work agreed with Gates' observations in almost every case with the exception that Lammert's temperatures were somewhat higher of the two. Armbruster commented on the few tables presented by Gates and explained that these tables became much more fruitful when arranged in graphic form. In brief, Armbruster believed that the brood nest temperatures never go below 93.2 degrees F. and seldom above 95 degrees F. He said that when the low level of 93.2 degrees F. occurred there was a direct response of the bees to prevent the temperature from becoming any lower; and that when the temperature reached 95 degrees F. there was a direct cooling off response by the bees so that temperatures would not rise above that point.

Hess in 1926 carried on some extensive experiments on the temperature of a colony of bees during winter and summer. He said that inside the brooding sphere 95 degrees to 96.8 degrees F. prevailed whenever extraordinary outside temperatures did not hold sway. He found a variation of only .36 degrees to .76 degrees F. during the course of a day, even though the outside temperature might cover a wide range of variation. He stated that the mechanical regulation of temperatures in bees is as steady as in humans; that is, they have an effective regulation toward low and high external temperatures. On a day in August, when the maximum outdoor temperature was 93.2 degrees F. he placed an electrically heated pad under a colony of bees and obtained a temperature over the honey comb of 104 degrees F., in the broodless region of 100.76 degrees F. and in the sphere of brooding of 96.8 degrees F. Hess thought that only the evaporation of water was effective in lowering the temperature in the brood area.

Milum in 1928 reported some of his observations. He said that apparently 91 degrees to 92 degrees F. were necessary to

stimulate the beginning of brood rearing, but that this temperature did not need to be maintained for the continuation of brood rearing. Temperatures as low as 76.3 degrees F. were observed with no apparent ill effects on the brood except that it retarded development. During the spring period, temperatures of 85 degrees F. in the brood nest were not uncommon. When brood rearing had become well established in late spring and summer, the brood area ranged from 90 degrees to 95 degrees F. The highest temperature recorded by Milum was 98.2 degrees F. Temperatures above 95 degrees F. tended to cause the bees to hang outside the hive.

Vansell reported in 1930 a temperature of 108 degrees F. in the brood nest when external temperatures reached 116 degrees F.

CONDITIONS UNDER WHICH THE EXPERIMENT WAS CONDUCTED.

This experiment was performed on the roof of the third floor of the Botany and Zoology Building of Ohio State University, Columbus, Ohio. This place was selected because it was a convenient location, the space was well adapted for an experiment of this nature, and moreover the experiment would be less disturbed here than in any other available place. The colony used in this experiment was of the Italian race of bees.

On June 18th, 1926, the colony in a ten frame standard hive was taken from the college apiary and placed on the roof of the third story near the place where the experiment was to be carried out. On June 30th, two and one-half pounds of young bees were added to the colony so that the total number of bees was 35,000–45,000.

After the colony had become adjusted to this location, it was set back on a platform within the building so it was on the same level as the bottom of a window casing. The lower half of the window was raised and the open space covered with beaver board. The entrance of the colony was extended out of doors by means of a tunnel 14½″ x 8″ x ⅞″. The outdoor entrance to this tunnel measured 4½″ x ⅜″.

Temperatures within the colony were taken by means of the electrical thermocouple method, but room and outdoor temperatures were taken with mercuric thermometers. The general set up of the compound thermocouple was similar to that outlined by Robinson in the Journal of Economic Entomology, 1927.

Each thermocouple junction was checked for accuracy against a tested mercuric thermometer covering the range of degrees in temperature that might possibly be involved in the experiment. There were eight thermocouple wires running into the hive at various locations, but all were placed at the same depth which was 4½ inches from the top of the hive. The ends of the wire at the thermocouple junction were placed in a thin glass tube, the end of which was closed. To prevent air currents, tape was wound around the open end of the glass tube and also at the place where the glass tubes pass through the inner cover of the hive. The reason for placing the thermocouple junctions in glass tubing was that we desired only representative temperatures of the region in which the thermocouple was located. The glass tubing tended toward avoiding any local influence such as a bee fanning its wings vigorously near the exposed junction, or the placing of propolis on the junction.

HIVE TEMPERATURES FOR THE DAY.

Two days after taking the hourly temperatures of the colony, it was examined and notes were taken on the exact position of the brood, the honey, and the empty comb space. The temperatures occurring within the hive were divided into three distinct classes; those occurring in the central brood area, in the outer brood area, and in the broodless area. Table I gives the temperatures occurring hourly during the experiment. Figure 1 gives a graphic representation of the temperatures prevailing hourly in the different regions within the colony. The two curves designated as room temperature and outdoor temperature represent the external temperature to which the colony was exposed during each hour of the day.

As shown by the curves, the influence of the environmental temperatures has very little, if any, influence on the temperatures of the central brood area. This is shown clearly as the difference between the maximum and minimum temperatures, 94.1 degrees F. and 93 degrees F. respectively, was only 1.1 degrees during the entire twenty-four hour period. This demonstrates the proficiency of the ability of the bees to maintain a very constant temperature in the central brood area when the external temperature is similar to that represented by the graph. It would seem then when comparing the central brood area temperatures with the curves rep-

TABLE I.

HIVE TEMPERATURES FOR EACH HOUR OF THE DAY.

July 28, 1926	Av. Temp. Central Brood Area	Av. Temp. Outer Brood Area	Av. Temp. Brood-less Area	Room Temper-ature	Outdoor Temper-ature
8:00 A. M.	94.1° F.	87.7° F.	85.2° F.	78° F.	68° F.
9:00	93.5	87.5	83.2	78	70
10:00	92.8	86.7	82.2	80	76
11:00	93.5	87.2	82.2	80	82
12:00	93.2	87.2	81.7	82	86
1:00 P. M.	92.6	87.5	84.5	84	90
2:00	93	89	85.7	85	100
3:00	93.2	90	87.2	86	104
4:00	94	91	88.5	88	106
5:00	93.7	92.2	90	88	108
6:00	94	92.7	91.2	88	100
7:00	93.7	93	91.5	88	90
8:00	93.4	92	91.2	87	82
9:00	93.5	91.7	90.7	86	78
10:00	93.4	91.7	90.7	82	76
11:00	93.5	91.2	89.5	82	76
12:00	93.5	90.7	89	82	76
1:00 A. M.	93.5	90.5	88.9	82	73
2:00	93.5	89.7	88.2	82	72
3:00	93.6	90	87.7	81	72
4:00	93	89.5	87.7	81	72
5:00	93.2	89	87.5	81	70
6:00	92.8	88.7	86.7	81	70
7:00	93	88.5	86.5	81	72

resenting external environmental temperatures that there was only a slight, if any, correlation between the temperatures occurring in the central brood area and external temperatures.

The curve representing the hourly temperatures in the outer brood area is extremely interesting as it shows that the tem-

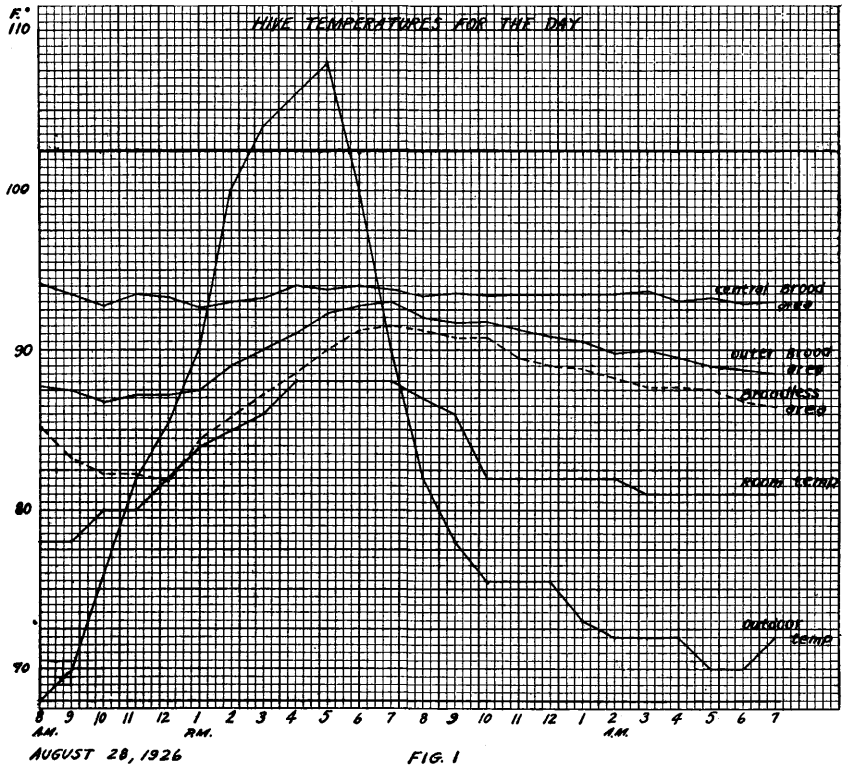

FIG. 1

peratures in this region are quite distinct from those occurring in the central brood area. The temperatures of the outer brood area most nearly approach those of the central brood area when the environmental temperatures to which the colony is subjected reach their highest level. With the gradual lowering of the external temperatures, as indicated in the graph, there is a greater deviation between these two curves. Stating this more directly when comparing the curve of the outer brood area with the curves representing the environmental temperatures, the temperature fluctuates to a certain extent with the rise and fall of external temperatures, such as occurred in this experiment.

The temperatures recorded hourly in the broodless area are the lowest of any region of the hive and when comparing this curve with the environmental temperature curves, it seems to be influenced to the greatest extent.

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