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THE TEMPERATURE OF THE BEE COLONY.[1]

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INTRODUCTION.

There has been a decided need of accurate knowledge of the temperatures and changes in weight of colonies of bees, particularly ring the winter. Previously existing data have not been gained under controlled conditions, but generally by casual observations, limited in number. Most of the previous work has also been for a short period of the year. In this work an effort has been made to get more reliable information by collecting data for practically the cycle of a year. The knowledge of the changes in temperature and weights is needed in a careful study of methods for successfully wintering bees. This is one of the greatest difficulties which the beekeeper has to meet, and it is hoped that the present work may furnish data for a further study of the wintering problem. The scope of the work here recorded is indicated by the following figures:

Period of experimentation, October 22, 1907, to September 26, 1908.
Number of observations, 2,576+.
Number of separate readings, 20,000+.

APPARATUS.

The apparatus was constructed to meet emergencies which might arise, which accounts for its many parts. It was planned so that the complete apparatus could be upon the scales at all times, thus obviating complications from corrections in weighings.

THE SCALES.

A finely adjusted platform scales was specially constructed, which registered with a sensitivity of 10 grams to a maximum of 200 kilograms. It was expected that it would be possible to record

[1] This report of work done for the Bureau of Entomology has been accepted by the faculty of Clark University, Worcester, Mass., as a dissertation in partial fulfillment of the requirements for the degree of doctor of philosophy, and accepted upon the recommendation of Dr. C. F. Hodge. The author has been appointed to the position of assistant professor of beekeeping, Massachusetts Agricultural College.

Note.—A study of the effects of temperature on bees, and of interest to beekeepers generally.

slight changes in consumption or increase of stores. By means of a double beam it was possible to counterbalance for extra thermometers or other small special apparatus which might be added temporarily, without necessitating a correction of the hourly readings. The scales were found to be relatively satisfactory, but in times of heavy wind extra precaution was necessary in order to overcome the influence of drafts on the scales. In winter this could easily be accomplished by closing the door of the shed in which the experiment was carried on. For outdoor work, however, some difficulty was experienced, as will be explained. The agate-set bearings were also sensitive to jar, which was constantly guarded against.

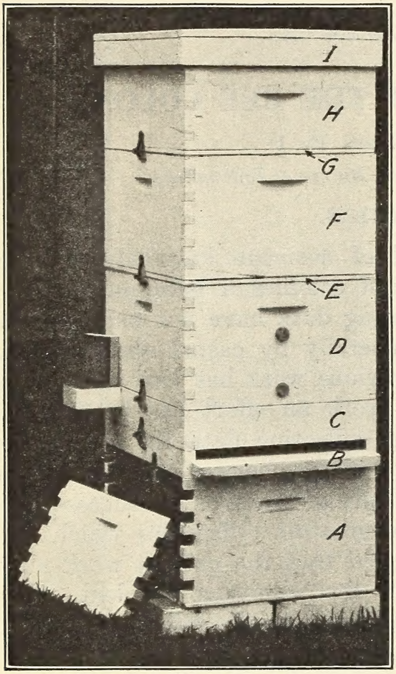

FIG. 1.—The hive used in the experiment on the temperature of the bee colony: *A*, storage chamber for accessories, with door; *B*, bottom board with entrance; *C*, collar with feeder; *D*, brood chamber; *E*, perforated zinc honey board; *F*, second story for surplus; *G*, thin board with holes for thermometers; *H*, case protecting thermometers *a–e*; *I*, outside cover.

THE THERMOMETERS.

Seven mercury thermometers were used, of the type known as incubator thermometers, which have a long stem and can be read to fifths of a degree. One instrument, however, used to register the temperature of the outside air was an ordinary chemical thermometer. These instruments were standardized and were graduated to the centigrade scale.

THE HIVE AND ITS APPLIANCES.

Figure 1 illustrates the general appearance of the hive, showing the five stories. Only one of these was occupied by bees, as will be explained. The hive was of the standard 10-frame Langstroth type. Throughout the experiment it stood on the scales (fig. 2). The several parts were as follows:

A. The lower part consisted of a hive body with one side removed. To the bottom was nailed a thin cover board, which served as the floor of the compartment. The purpose of this chamber was to store fixtures, such as frames, "dummies," extra thermometers, and the like, while they were not in use. In this way it was unnecessary to compute in the weighings for any change in the apparatus. For example, in the winter, when four frames in the brood chamber were replaced by the "dummies," these were taken from the storage chamber and the frames hung in their place, without altering the weighings.

B. An ordinary bottom board.

C. This wooden collar contained the feeder and increased the space between the bottoms of the brood frames and the bottom board. thus allowing the insertion of a thermometer below the frames. The feeder was what is known as an Alexander feeder. The end may be seen extending out of the collar at the rear of the hive. In this projection, which was provided with a wooden cover, the sugar sirup is poured without disturbing the hive. The cover prevents drafts of air through the feeder.

D. Above the collar was the hive body in which the bees were located. The frames were spaced with metal spacers (fig. 3), and wedges between the central frames held all firmly in place. In this way everything was sufficiently secure to enable any possible manipulation, even to turning the hive upside down, should it be necessary, without displacing parts. The wedges also increased the space between the central frames sufficiently to allow for the insertion of the stems of thermometers. The gauge in frames 3 and 4 permitted the insertion of thermometer *e* (fig. 3). The frames were wired and filled with full sheets of foundation before insertion. Two holes were bored in the middle of the front above the entrance, for use in case it should become desirable to insert thermometers. Throughout the experiment these were closed with corks.

E. Between bodies *D* and *F* was a perforated zinc honey board.

F. A second body was provided in case more comb space should become desirable.

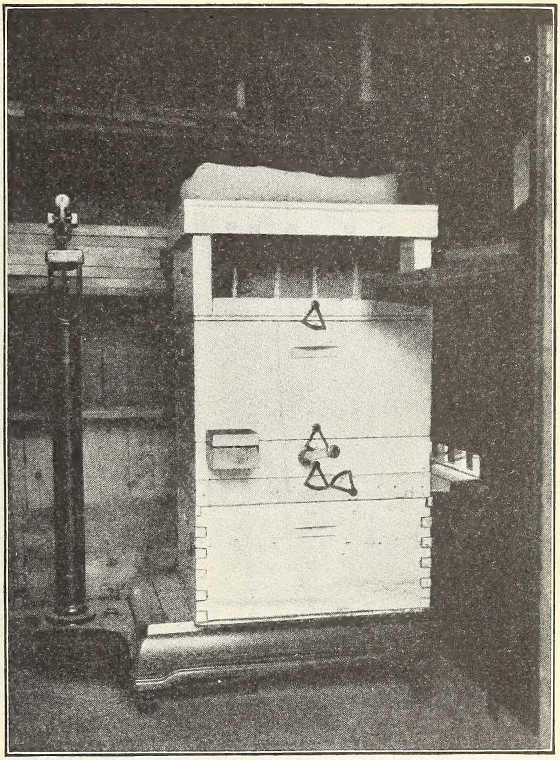

FIG. 2.—Hive on scales in shed where it was kept during the winter.

G. The top of the hive proper was covered with a thin cover. This, as is shown in figure 3, had four holes drilled in the median line and one directly over the rear part of the space between frames 3 and 4. Through these holes thermometers fitted in corks were inserted.

H. This was a special hive body used as a protection for the thermometers. One side, shown in figure 2, was removable so as to permit easy reading of the instruments. In this chamber and around the thermometers were two cushions of ground cork, for the protection of the tops of the thermometers and for the conservation of the heat of the cluster in the extreme of winter.

I. A metal cover.

A series of clamps, which drew over screw heads, held the several parts firmly together, preventing the bodies from sliding and snapping the stems of the thermometers.

The "dummies" above mentioned consisted of ordinary frames into which boards were fitted snugly. These were used in the winter months instead of the two outside frames on either side of the hive, thus forcing the cluster to occupy six frames in the center of the brood chamber. In this way it was made certain that the cluster would not shift away from the thermometers during the winter. The

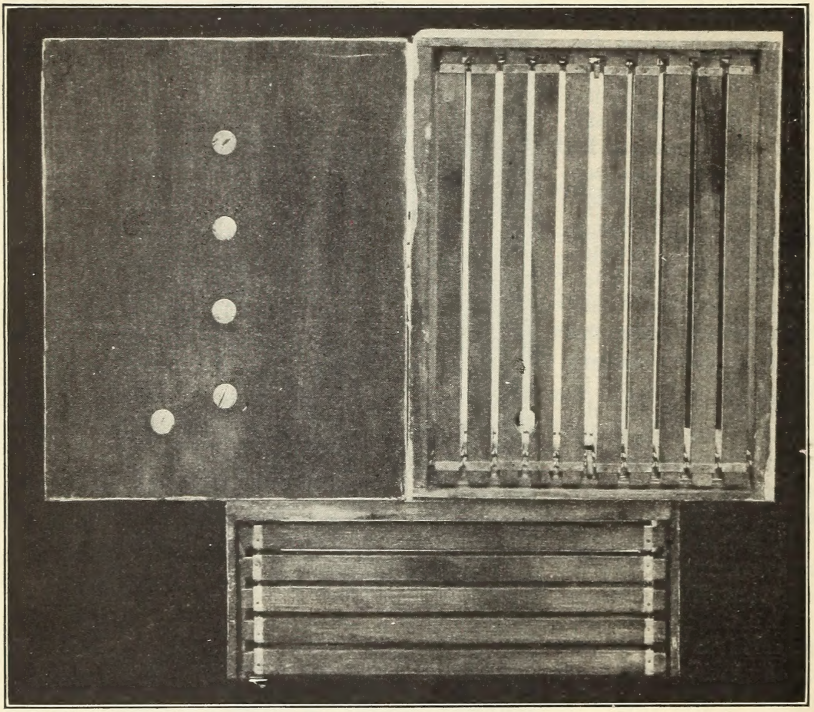

FIG. 3.—The hive from above, showing the spacing of the frames. The corks in the cover indicate the location of the thermometers.

"dummies" were removed when brood rearing became established in the spring. These were not intended primarily for protection and did not fit the hive tightly.

In order to eliminate the annoyance and possible complications from propolizing, all the interior wooden parts were varnished and polished to a piano finish.

It should be said that not all of the parts of the apparatus provided were pressed into service. The extra body, *D*, was not needed, and consequently the honey board, *E*, was not used. The outfit as actually used and as it appeared in position until the writer was forced to move the experiment to the country in July, 1908, is shown in figure 2.

THE BEES.

Throughout the experiment Caucasian bees were used. Two colonies were necessary. The first drew out the foundation in the frames and was used during September and October, 1907. The second was hived in November, 1907, and served throughout the remainder of the experiment. This colony did not swarm.

THE ARRANGEMENT OF THE THERMOMETERS.

The thermometers were designated *a, b, c, d, e, f*, and *o*. Thermometers *a, b, c*, and *d* were inserted between the central combs. They were arranged at regular intervals, *a* being at the front of the hive and nearest to the entrance. Thermometer *e* was placed at the rear of the hive between combs 3 and 4, and was expected to represent the temperature of the margin of the cluster. Thermometer *f* was inserted beneath the frames through the collar, as is described above. Its purpose was to record the temperature of the air below the cluster and which was likely to be affected by currents from the entrance. Its bulb was directly below the central frames. The first five thermometers extended about 7 inches below the cover. The outside thermometer, *o*, was suspended close to the hive in such a way as to register the temperature of the air which surrounded the apparatus.

LOCATION OF APPARATUS.

The apparatus was installed in a shed on a third-story back piazza in southwest Washington, as is shown in figure 2. While the shed afforded shelter from storms, which was necessary for the protection of the apparatus and in taking observations, windows and door were left open, making the conditions relatively like out of doors. The shed was on the south side of the building.

In July, 1908, it was necessary to transport the experiment to College Park, Md. This, however, was found not to have affected the results. The apparatus was arranged in a situation comparable to the shed in Washington.

CHECK COLONY.

Besides the colony on the scales, in which the thermometers were suspended, a check colony in a hive with glass top and bottom was set up close by. The hive was constructed with a glass bottom board, and a wooden shield to cut out light. The cover was also of glass sealed to the hive, on top of which were several thicknesses of felt paper and an ordinary hive cover. By removing the bottom shield and the top protection it was possible at any time of day or night to look between the combs at the cluster. These protective coverings were applied so as to be removed with the minimum jar. At night, or even in the daytime, by means of a reflector, lantern light could be thrown up between the frames. In this way the writer was able to watch from day to day the shifting of the cluster and the reaction of the bees to their environment and to compare this with the readings of the thermometers in the hive on the scales. It was necessary to maintain this check only during the winter period.

METHODS OF OBSERVATION AND RECORDING.

Since none of the instruments recorded automatically, it was necessary to make frequent readings of both the weights and temperatures. The experiment proper lasted from October 22, 1907, to September 26, 1908. The first colony, used to prepare the combs, was also under close observation, so that the whole period of experimentation was almost a year. Readings were taken at least every hour throughout the working day. Whenever the hive was manipulated, or when peculiar meteorological conditions prevailed, readings were taken half hourly, or even quarter hourly. On the average of about once in three weeks, by means of assistance, it was possible to take consecutive hourly readings for a period of two or three days. In this way practically the whole activity of the colony for a period of a year was recorded. During the summer months the readings usually covered a period of 14 hours daily.

The temperatures were read to fifths of a degree. Weighings were made to 10 grams. Every alteration or manipulation of the colony was recorded. Hourly changes in the weather and activity of the bees were also noted.

The readings were recorded on 12.5 by 20 cm. cards, the size standard to the office note file. Later from these tables the curves of the temperature and weights were plotted on millimeter cross-section paper, one sheet to a month. The method of plotting is obvious from examination of the several curves herein presented.

THE CONSUMPTION OF STORES IN WINTER.

At the outset of the investigations it was hoped by means of delicate scales, which have been described, that sufficiently accurate weighings could be made to show whether there is any correlation between the loss in weight and the temperatures of the cluster in winter. For instance, it was desirable to know whether there is any relation or rhythm in the consumption of stores to changes in temperature due to metabolism. It has not been possible to detect any such relations. Nevertheless several significant facts concerning the consumption of winter stores have been discovered.

The rate of consumption of stores, as is shown in figure 4, exhibits a relatively constant decrease from month to month. At the beginning of the season, before the cluster was well established, when bees were more active and before settled winter weather, food consumption was greater than in midwinter. As the season progressed, during February, for instance, consumption slackened. There are several factors which may account for this. In the first place, as the winter advanced there were fewer and fewer bees to be fed. The winter was also less severe, and consequently less generation of heat was necessary.

Humidity is another factor which noticeably influenced the daily weights for a considerable part of February. This also occurred

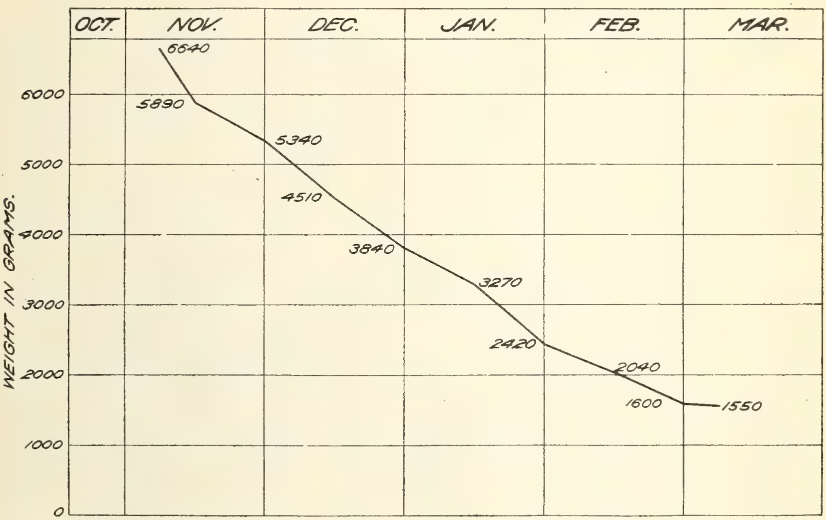

FIG. 4.—Graphic representation of the loss in weight of the bee colony from November 6 to March 7, due to the consumption of stores.

periodically in other months. Although condensation tended to prevent a drop or even to raise the curves during a period of bad weather, as will be shown below, the increased weight due to the condensed water vapor could neither be permanent nor affect the total loss of weight during so long a period as a month. Whatever water condensed during inclement weather would evaporate during the following days of fair weather. Thus, while the scales might register an increase during bad weather, consumption of stores was actually going on all the time, but could not be detected in the weights until fair weather had dispelled the moisture. Consequently the records of single days are less significant than the averages of a month or of the season.

There was, however, a gradual and constant lessening of the daily consumption of honey, as is apparent in Table I, which presents the monthly and average daily figures. From this table it will be seen that while in November the average daily consumption was 53.2 grams, in February the average was but 30 grams a day. For the entire winter 43.5 grams of honey were consumed, on the average, daily.

TABLE I.—*Monthly and average daily consumption of stores by wintering bees.*

Time.	Weight of stores.	Monthly loss.		Average daily loss.	
	Grams.	*Grams.*	*Pounds.*	*Grams.*	*Grains.*
November (Nov. 6, 9 a. m., to Dec. 1, 9 a. m.—25 days)	6,640 5,310	1,330	2.932	53.2	821
December (Dec. 1, 9 a. m., to Dec. 31, 9 a. m.—30 days)	5,310 3,820	1,490	3.284	49.6	765
January (Dec. 31, 9 a. m., to Feb. 1, 9 a. m.—32 days)	3,820 2,470	1,350	2.976	42.2	651
February (Feb. 1, 9 a. m., to Feb. 29, 9 a. m.—28 days)	2,470 1,630	840	1.852	30.0	463
Total loss for 4 months		5,010	11.045		
Average daily loss				43.5	671

TABLE II.—*Daily loss in weight of colony of wintering bees.*

Date.	Loss in grams.	Date.	Loss in grams.	Date.	Loss in grams.	Date.	Loss in grams.
Nov. 11	120	Dec. 10	+30	Jan. 10	70	Feb. 10	0
12	10	11	70	11	40	11	20
13	50	12	70	12	+10	12	20
14	70	13	60	13	30	13	0
15	50	14	20	14	50	14	+40
16	80	15	25	15	60	15	+20
17	90	16	25	16	40	16	130
18	60	17	60	17	50	17	20
19	10	18	40	18	50	18	40
20	70	19	40	19	40	19	+40

Although the foregoing figures represent the usual daily conditions, they do not by any means represent the actual daily consumption. As will be seen in Table II, there was no such degree of constancy as is represented by these averages. Taking the 10 days at the middle of each month, it is possible to represent prevailing conditions for that month. Thus the data of Table II are a fair representation of the actual variations as they occurred during the winter. It will be seen in this table that the daily variation in weight is all the way from a loss of 130 grams in some cases to no loss whatever or even an increase of 40 grams. Therefore it is hardly possible to assume that the weights of the entire hive will throw any light on the amount of honey consumed in a single day.

This increase in the weight of the hive during bad weather is a fact which, so far as the author is able to learn, has not heretofore attracted attention. It can not be said in any wise that this is an increase in the amount of stores. The phenomenon usually accompanied wet weather or fog and must be attributed to condensation of moisture. In the check hive moisture was frequently seen collected on the glass top and even on the frames and bees, but there the conditions were perhaps less normal than in the experimental colony. Root[1] says that he has seen confined moisture cause icicles to form in the hive. The condensation may become so great in extreme cases as to cause the bees to freeze together in a solid block when chilled down by severe cold. (Root, pp. 332–334.)

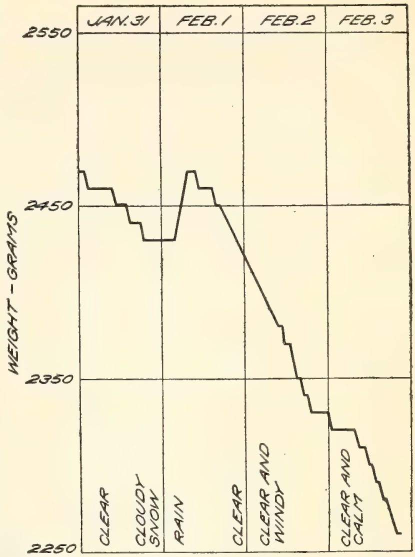

FIG. 5.—Curve showing changes in weight of the bee colony from Jan. 31 to Feb. 4.

Honey is well known to be hygroscopic, and if put into an ice chest or a damp cellar, it takes up moisture. Extracted honey has also been observed to accumulate enough moisture to dilute it considerably. In the present case the hygroscopic property of the honey can not be held wholly responsible for the increased weight, although it may have contributed. Following an increase of this kind, as has been mentioned, there was a marked decrease with the coming of fine weather and dryness. For illustration, the increase of 40 grams on February 1 (fig. 5) occurred during the early part of the day, when it was raining. That afternoon and the following day there were fair weather and wind. Then there came a marked decrease in weight, which not only compensated for the increase during the storm, but also showed that stores had been consumed constantly, although the weights

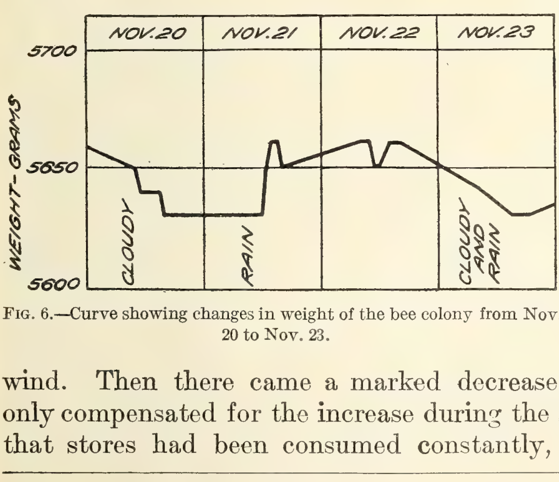

FIG. 6.—Curve showing changes in weight of the bee colony from Nov. 20 to Nov. 23.

[1] A B C and X Y Z of Bee Culture, 1908 ed.

failed to demonstrate it at the time. This same point is illustrated by the figures presented in figure 6. Such conditions suggest the complications which arise in attempting to correlate the colony temperature with the consumption of honey.

GENERAL PHENOMENA OF THE CLUSTER IN WINTER.

During the winter the bees are relatively quiet; the cluster expands and the bees fly only in the warmth of the warmest days. The heat maintained in the cluster has a general relation to the prevailing temperature of the air.

This relation of the cluster temperature to air temperature is especially evident in a comparison of the maximum and minimum temperatures of the several thermometers of the hive with the temperature at the outside thermometer, *o*. The daily maxima and minima were practically synchronous for all of the thermometers with the exception of *c*, which usually had its maximum when the temperatures registered by the other thermometers were lowest. Conversely, the minimum of *c* occurred when the outside thermometer and the others in the hive were at their highest points. This will be explained in detail under a following caption. With the exception of *c*, then, and for the particular conditions under which this colony was kept, the minima occurred daily some time between 6 a. m. and 12 m., but usually about 8 or 9 o'clock. The maxima occurred daily in the afternoon, usually between 2 and 4 o'clock.

While *c* registered the highest in cold periods, the temperature recorded by the other thermometers showed a similarity with the prevailing temperature of the air. Thus, in periods of cold, as for example in December, the thermometers in the hive as a whole registered lower than they did in warm periods. In warm periods, when the bees are able to expand the cluster and move about, the maximum cluster temperature lacked but a few degrees of the maximum summer temperature. This is repeatedly shown in figure 7; and in March, on a warm day, the temperature reached the extreme of 33.2° C. (91.76° F.). The temperature of the cluster did not fall below 17° C. (62.6° F.), and usually the bees did not permit the temperature of the cluster to fall below 20° C. (68° F.).

The amplitude of the fluctuations between the maximum and minimum temperatures showed a close relationship to the external conditions. In the center of the cluster, for instance, *c* registered much more constantly than the thermometers in the outside layer of the cluster. The daily oscillations of *c* were usually not greater than 1 to 5 or 6 degrees Centigrade. On the contrary, in the case of the other thermometers in the hive which were more affected by the rise and fall of the temperature out of doors, the amplitude of the oscillations was as great as 3 to 20 degrees Centigrade. The center of the cluster, therefore, shows more clearly the activities of the bees. The active portion of the cluster has a higher and more uniform temperature than the other parts, while the outside layers are subject more directly to the fluctuations of the winter weather. Most of the following study of the winter conditions of the beehive will be based on the records of the center of the cluster.

It would naturally be expected that the heat radiating from the bees would tend to delay the effects of the penetration of the cold of the outside air on the cluster. In other words, it might readily be expected that the cluster thermometers would reach their maxima and minima later than the outside thermometer. However, this occurred seldom and only in severe weather, when the changes were rapid and considerable. Even then there was a delay of only an hour or two at the most. This again suggests the sensitiveness and the responses of the cluster to the changes in the external air. The adaptation of the bees to changes in the atmospheric conditions will be more apparent when details are considered.

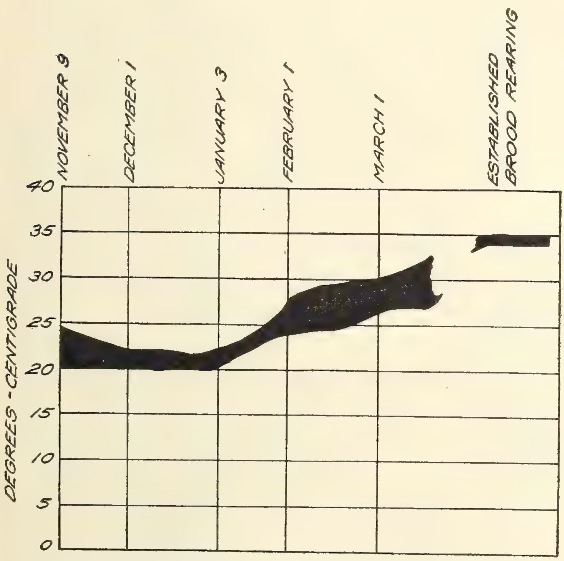

FIG. 7.—Schematic curve showing cluster temperatures of the bees during the winter and after brood rearing began.

As has been suggested above, there was a tendency for the cluster gradually to maintain a higher temperature as the season advanced toward spring and the beginning of egg laying. The schematic curve, figure 7, presents graphically the conditions of temperature at thermometer *c* throughout the winter. It will be noticed that during the month of November, when the bees were less definitely and constantly clustered, the amplitude of the daily variation and the general temperature of the cluster were higher than in the succeeding months. This is also evident in the fact that the curve of the thermometer *c* at this time of the winter tended to follow the curve of the outside thermometer *o* to some extent. In December, however, there was a change in the course of the temperatures at *c*, in response to the change in outside conditions. The conditions remained more nearly constant from this time until egg laying commenced in the spring, except that as the weather tended to warm up at the approach of spring the mean of the cluster temperature also raised. Finally when the days had considerably lengthened and were relatively warm, the amplitude of the cluster variations increased, as is shown in the schematic curve (fig. 7). When the summer season for the bees began, accompanied by the beginning of incubation, the temperature of the center of the cluster rose to 34° C. (93.2° F.) or 35° C. (95° F.) and continued practically at this level. For the winter, then, it might be said in a general way that the temperature prevailing for several days is in a measure an index of the temperature of the cluster.

TEMPERATURE BELOW FRAMES IN RELATION TO OUTSIDE AIR.

The thermometer *f*, situated below the bottom of the frames and cluster, as is shown in the general views of the apparatus (figs. 1 and 2), registered the temperature of the air at the bottom of the frames. It should have shown, if they were present, the effects of the cluster on the temperature of the air below the frames. It might be expected that the presence of the bees would have raised the temperature of the air in this part of the hive. For comparison with the other temperatures, thermometer *o* was hung in the shed in which the experiments were conducted, and registered the temperature of the air which enveloped the hive. Comparison of the readings of thermometers *f* and *o* reveal some significant facts not altogether in accord with the general belief of beekeepers.

During the winter as a whole these thermometers registered almost identically. Slight variations occurred, but only for a few hours at a time, and may be attributed to minor influences of the cluster, to peculiar atmospheric conditions, to drafts, and to the agitation of the bees. It should also be noted that the air which came in the entrance entered from outside the shed and the temperature of this air may not have been exactly that recorded by the thermometer *o*.

During the period of most protracted cold, from January 23 to February 1, when the outside air ranged about 0° C. (32° F.), thermometer *f* followed the outside temperature closely, and the course of the two curves is practically the same. In some cases, as for instance on January 26, thermometer *f* was slightly lower than the record of the outside air, which may possibly be explained by lack of ventilation or stagnation of the air of the hive. The lowest recorded outside temperature was −10° C. (14° F.). Since it was impossible to read these low temperatures on instrument *f*, and since the two curves are parallel so far as records were possible, it may be assumed that thermometer *f* would have registered almost the same as thermometer *o*.

During the warmest days and nights the recorded temperatures were the same. The maximum for the winter period came on March

15, when the outside thermometer reached 22.6° C. (72.68° F.). In all the other winter months there were days when the thermometers registered only 2 or 4 degrees less.

In conclusion it may be said that throughout the season the temperature below the frame was practically the same as that of the outside air. Of special significance is the fact that the daily extremes, the maxima and minima, no matter what were the variations at other periods of the day, were usually identical. From these observations

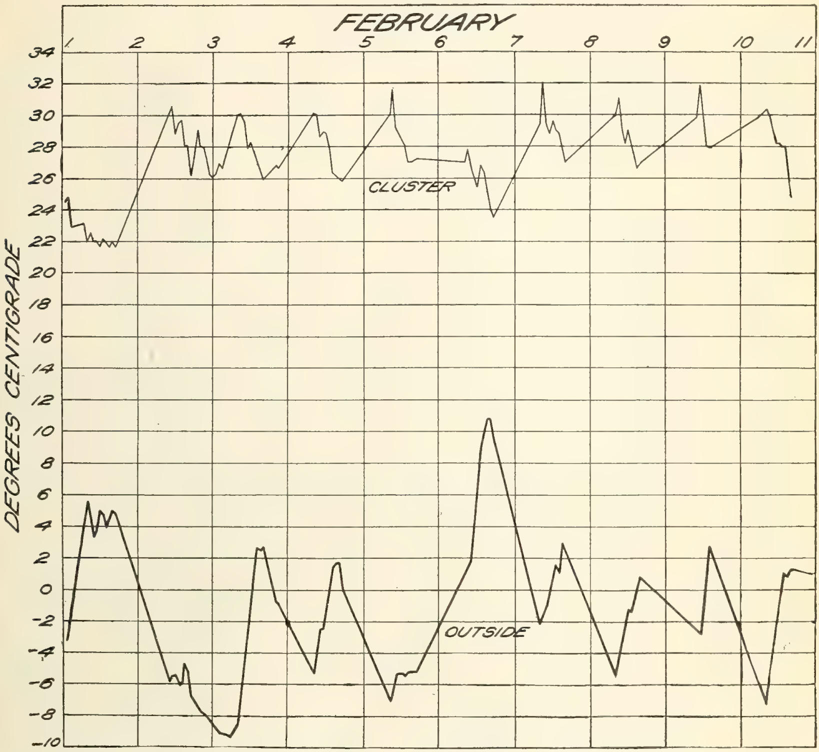

FIG. 8.—Curves showing relation of temperature of center of bee cluster to outer temperature, Feb. 1 to 10.

it would appear that the contraction of the entrance and the tight bottom board were not of much service in protecting the colony from cold. Colonies without bottom boards have frequently been known to survive extreme winter cold. It may be, however, an advantage to a colony to be protected from the sweep of violent winds; but there is no evidence that this colony appreciably warmed the lower part of the hive in which it was wintering. Under such conditions the bottom of the cluster is bathed in an atmosphere of the same temperature as the outside.

COMPARISONS OF TEMPERATURES OF THE CENTER OF THE CLUSTER AND OF THE OUTSIDE AIR.

The curves have revealed no more striking results than the relation observed between the temperature in the center of the cluster, *c*, as compared with the temperature of the outside air, *o*. These curves (fig. 8) at times show a peculiar inverse relation; for instance, when the thermometer out of doors registered low, below zero, the thermometer in the center of the cluster registered high, and vice versa. It should be observed that the maximum within the cluster occurs practically simultaneously with the minimum outside, and vice versa. Even minor changes outside are accompanied by corresponding inverse fluctuations in the cluster. The responses of the cluster to the outside temperature were shown particularly by the thermometer which recorded the temperature of the center of the cluster, *c*.

Up to the day of the first egg laying in the spring, March 9, the general courses of *c* and *o* continued relatively constant. But with the commencement of egg laying *c* changed its trend. The temperature of the brood cluster then became more and more constant, as may be seen in the results of the summer observations.

At first glance these curves might be interpreted as independent of each other, that the outside atmosphere has no effect on the center of the cluster, that it does not penetrate and modify the readings of *c* as it appears to have done in the case of the temperatures in the margin of the cluster. In all probability *c* more nearly represents the activities of the bees than do the other temperatures; but there is a relation of *c* to *o*. It might be supposed that the reaction registered by *c* is deferred for a period of hours and consequently appears at a time when *o* has changed. For instance, corresponding to the minimum of *o* on the 4th of February, the minimum of *c* came nine hours later. If this is due to a delay or "lag," maxima and minima in some cases are delayed for 24 hours or more. But this can not be; there are many minor variations which appear on the curves, and which are synchronous. Were there no relation of *c* to *o* these minor variations would either not have appeared in *c*, or, more especially, they would not have occurred simultaneously with a minor fluctuation in the outside temperature. It is therefore impossible to explain the phenomena on the ground of retardation (lag), for in that case it would be far more constant than is evident.

Related to the assumed explanation by delay or "lag," humidity or condensation, convection, radiation, and conduction might be assumed to be factors involved. The experimental colony furnishes no data for a consideration of humidity or condensation. The factors of convection, radiation, and conduction can not be conceived as slow enough to retard *c* from 9 to 24 hours nor would it account for its minor, synchronous variation. Without doubt of these three factors the loss of heat from the cluster by convection is sufficient to counteract the hypothesis of the lag. Coupled with this the other factors would be expected to participate. The convection is also modified by the generally known contraction and relaxation of the cluster, referred to elsewhere.

These physical phenomena are evidently unsatisfactory as an interpretation from this standpoint of the lag. Thorough comparison of the charts fails to provide suitable material for conclusions as to the cause.

Table III shows the relative increase of temperature in the cluster corresponding to the progress of the winter season, while Table IV shows the monthly maximum and minimum temperature of the center of the cluster during the period from November 9 to March 9.

TABLE III.—*Relative increase of temperature in the bee cluster corresponding to the progress of the winter season.*

Month.	Range of temperature.	
	°C.	°F.
November, beginning of winter conditions	20 to 24	68.0 to 75.2
December	20 to 22	68.0 to 71.6
Jan. 1 to 18	22 to 25	71.6 to 77.0
Jan. 19 to 31	23 to 28	73.4 to 82.4
February	24 to 30	75.2 to 86.0
Mar. 1 to 9	27 to 32	80.6 to 89.6
When brood rearing is established	34 to 35	93.2 to 95.0

TABLE IV.—*Monthly maximum and minimum temperature of the center of the bee cluster during the winter period, Nov. 9 to Mar. 9.*

Month.	Temperature of cluster.	
	Maximum.	Minimum.
November	27° C.	17° to 18.2° C.
	80.60° F.	62.60° to 64.76° F.
December	18.5° and 31.3° C.[1]	18.1° C.
	65.30° and 88.34° F.	64.58° F.
January	30.2° C[2]	19° C.
	86.36° F.	66.20° F.
February	32° C.[3]	21° C.
	89.60° F.	69.80° F.
Mar. 1–9	33.2° C.[4]	27° C.
	91.76° F.	80.60° F.

[1] On a very warm day, Dec. 28.
[2] This occurred on two occasions, Jan. 14 and 30, at 8 a. m., when the outside temperature was 4° C. or more below freezing.
[3] Approximated several times when outside temperature was below freezing.
[4] Occurred after a warm day; approaches summer conditions

EFFECTS OF MANIPULATION ON THE CLUSTER.

Good beekeepers know that it is not well to open a hive in winter, but perhaps few realize the resulting effects on the colony. In Washington there are days in every winter month which are sufficiently warm to permit opening a hive without chilling the bees. It was necessary, partially in order to observe the effects on the colony and partially to know their condition, to open the hive under experimentation. The results recorded by the thermometers on all of these occasions are pronounced. In the course of the observations on this colony it was found impossible to disturb the colony in the slightest degree, even to remove and replace a thermometer, to jar the colony, or to puff smoke in at the entrance, without noticeably affecting the temperature. These effects, as in the case of opening the hive, were not always temporary, but sometimes lasted for hours. Any disturbance resulted in an almost immediate rise in the temperature, and was appreciable throughout the cluster.

On March 12 the colony was opened for 15 minutes at 1 o'clock in the afternoon. The thermometers throughout the hive and even the one below the frames to some extent registered an immediate rise in temperature. When the hive was closed the cluster was soon reestablished but it was several hours before the temperature in the margins of the cluster became normal. On the interior of the cluster, however, the excitement and its effects were not so soon overcome. The curve for *c* shows that not until the next day did conditions approximate normal; the effects were appreciable even the day following the opening of the hive.

These results agree with the experience of many practical beekeepers, who consider it unadvisable to open their hives during the winter.

BEHAVIOR OF THE CLUSTER IN WINTER: OBSERVATIONS ON THE CHECK COLONY.

By means of the check colony with glass top and bottom, described on pages 5–6, it was possible to watch the movements of the bees throughout the winter at any time of day or night.

Various theories have been advanced by beekeepers to account for the behavior of bees in winter, but the writer is not aware that they are based on continuous and close observation. For instance, it has been maintained by some that bees semihibernate; by others it is affirmed that there is at intervals a general warming up of the colony in order that it may feed. The theory is that at stated periods bees generate enough heat to enable them to brave the cold and to expand the cluster sufficiently to enable them to reach fresh stores. It is not necessary to multiply theories on the condition and activities of bees in winter.

In a previous portion of the text the relation of the temperatures of the cluster to the temperature of the outside air has been sufficiently considered. It remains now to describe the activity of the bees as seen in the glass check hive. In some respects the movements or the reaction of the bees, and more particularly of the cluster as a whole, to the stimuli of changes in the atmospheric conditions was rather pronounced.

In watching this colony it was found that the density, and consequently the shape of the cluster, varied from day to day. When the air outdoors was warm, the cluster expanded; with cold, it contracted. The expansion usually did not cause the bees to cover more frames, but caused them to cover more completely those frames which they were occupying. Thus the expansion was usually downward toward the bottoms of the frames and in the direction of the entrance. With cold, the bees receded from the bottoms of the frames and from the top bars.

At all times the colony was sensitive to the slightest jar. The bees were also especially sensitive to the light which burst in upon them whenever the covering of the glass top was removed. If the hand were passed over the glass, bees would fly toward it as if to sting. This was noticed no matter how cold the day and shows that the colony, and particularly the outside of the cluster, is far from torpid, inactive, or semiquiescent. At practically all times there were bees moving on the outside of the cluster or on the top bars of the frames. Whenever the hive warmed up in the sun, although there were no bees flying, this was evident. There can be no question, therefore, of the alertness and activity of a colony in winter.

One of the most surprising observations was the apparent interchange of bees from the inside of the cluster with those on the outside of the cluster. As the writer watched the cluster, the head of a bee would gradually appear from below the bees forming the shell of the cluster. Finally this bee emerged and took her place with the others on the outside. Similarly, bees were frequently seen to disappear into the mass. The behavior was in no way general, but apparently was going on constantly and gradually. The phenomenon was repeatedly observed under all manner of conditions and at different times of day and night. By carefully arranging the covers, so that it was unnecessary to remove them, and thus cause a jar, it was proven that this behavior is normal and not the result of a disturbance of the bees. It must be concluded, therefore, that in this way the same bees may not be exposed to the outside cold for a long period. So long as they are able to keep up their own body temperature they remain outside, but when chilled they pass into the interior. Thus there must be a continual interchange of bees from the outside to the inside. Were it possible of observation, there would doubtless be found a relation of the interchange to the meteorological conditions. In cold weather the interchange may be expected to be greater.

In severe weather the bees were especially compact and their arrangement definite and constant. They were arranged side by side between the tops of the frames, with their heads downward. At the lower part of the cluster they were also arranged head down but with a little less regularity. It is difficult to see just what this means.

As further evidence that the colony is not torpid in cold weather, some of the other activities observed will be of interest. During the day, particularly, the bees were seen grooming and combing one another, feeding, and fanning at the outside of the cluster; and when the light was admitted to the top, they sometimes flew up as if to sting. It should also be stated that on nights of the most severe weather the bees in both this check colony and in the experimental colony were heard faintly and intermittently buzzing. This buzzing was even more noticeable on cold nights than on warmer ones. A peculiar trembling of the bee such as is seen in summer was not infrequently noticed. All of these activities are commonly observed in summer, but heretofore have not been thought to occur in winter and spring before the colony is able to fly forth.

It is probable that the heat of the sun has no slight influence on the cluster. At least in the check colony under observation it was evident that the cluster sought the sunny side of the hive, the front above the entrance, where from 10 or 11 o'clock in the morning until sundown the sun shone on the hive.

TEMPERATURE ACCOMPANYING THE LAYING OF THE FIRST EGGS.

With the laying of the first eggs in the spring, which marks the beginning of summer activity, striking changes occur in the behavior and temperature of the cluster. The central thermometers *b* and *c* were particularly affected. Upon opening the hive March 12 eggs less than three days old were discovered. Up to March 9 *c* had usually continued its winter course inversely to *o*, as is described and illustrated above by figure 8. But after March 9, when the first eggs were seen, the course of *c* changed and the inverse relationship was no longer apparent.

In order to explain the change in the course of *c* in relation to *o*, the behavior of the bees at egg-laying time must be considered. During the winter, while fresh air is necessary, there is no such need of it as when the eggs, or more particularly the brood, appear. Moreover, for incubation and for brood rearing a much higher and more constant temperature is needed. The effects of drops in the temperature of the outside air must be overcome. In preparing room for the laying of the queen, the zone for the brood nest is established, which is an important factor in the change in the course of curve *c*. All of these things appear immediately in the curve at the time of incubation. Formerly, when the bees went forth on a warm day there was a drop in *c*; now the trend of *c* is slightly upward during the warmth of the day corresponding somewhat with the warmth outside. Flight occurs nearly every day.

It is the belief of many beekeepers who winter their bees in cellars that too high a temperature is likely to cause uneasiness and brood rearing. Root (1908) calls attention to the necessity of maintaining a temperature of not more than 45° F. (7.22° C.) at the approach of spring. The writer is not aware that any systematic study of the temperatures of bees in cellars has ever been made, so that it is impossible to say how the temperature of the cluster would compare with that of the colony under experimentation. The prevailing outside temperature, however, in the present experiment was found to be about 45° F. (7.22° C.) for several days previous to the laying of the first eggs, March 9.

At any rate in this experiment it appears that a temperature of 45° F. (7.22 C.), with an occasional maximum outer temperature of 8° to 11° C., is closely associated with the beginning of egg laying. But there are probably other factors of importance, particularly the matter of food. In establishing the experimental colony late in the fall, it was impossible for the bees to store any pollen. In the spring, however, for a week previous to egg laying they were seen gathering it. This might be expected to be an important stimulus to egg laying, and the bees could not rear brood until some could be gathered. While there appears to be a close relation between stimuli, temperature out of doors, and pollen gathering to the laying of eggs, details of the phenomena can be worked out only on a larger number of colonies under experimental conditions.

Another noticeable phenomenon which occurred at this time was the equalization of the temperature throughout the cluster. This might occur earlier in colonies protected from the winds and in sunny locations and later in colonies less favorably situated. If, however, upon experimentation this should be found to be one of the fundamental stimuli to egg laying, it would in a measure explain the fact that eggs do not always appear at the same time in all of the colonies of a bee yard. Another factor would be the strength of the colony and the resulting heat which it could produce and conserve. These results of the present investigation suggest great possibilities for discovering the stimuli which regulate the beginning of egg laying in the spring and which might influence the periodicity of brood rearing during the summer.

So far the consideration has been largely of the period in which eggs were laid and which preceded directly the beginning of incubation or brood rearing. It will be seen, therefore, that this time is in a sense transitional from the winter condition to the summer season, the topic which will next be considered.

TRANSITION FROM WINTER TO SUMMER CONDITIONS.

The phenomena mentioned in the preceding caption which accompanied the laying of the first eggs marked the beginning of the transition from winter to summer conditions, but this transition was not completed until brood rearing was well established. With the establishment of brood rearing, the changes which manifested themselves with the first eggs became intensified. The course of the temperature recorded at *c* became unlike that which was observed in the winter and was influenced more directly by the outside temperature. The influence of the outside temperature became less and less marked, as is shown from the fact that the oscillation of *c* became less and less, the temperature in the center of the cluster became more constant, and the temperature throughout the hive became more equalized. As was stated, the turning point came on the 9th of March, but it was a little more than two weeks, about the 24th or 25th of March, before the colony really assumed normal summer temperature condition. Once this was gained, the temperature, particularly of the center of the cluster, remained relatively constant until fall. This transition period of two weeks was characterized by several features.

There was an increase of temperature both in the colony and out of doors. Out of doors the maximum ranged between 12° and 18° C. (53.6° to 64.4° F.), but even more favorable weather followed the establishment of brood rearing and the maximum ranged from 18° to 25° C. (64.4° to 73.4° F.). To a certain extent the temperature of the colony was raised like that of the outside temperature. The increase was general throughout the colony and must be attributed to the need of more heat for brood rearing, more ventilation, and the general increased activity of the bees. At this time *b* and *c* ranged constantly between 33° and 35° C. (91.4° to 95° F.), which will be seen to be practically the range throughout the summer.

In a word, the transition from winter to summer conditions was accomplished in a surprisingly short time. Accompanying incubation and brood rearing the temperature was gradually raised and became equalized through the hive, and once well established was maintained during the summer. Although the transition was relatively abrupt, it would be expected to vary with the colony and perhaps be prolonged in unfavorable weather.

GENERAL PHENOMENA OF THE SUMMER TEMPERATURE.

The constancy and equalization of the temperature and the range of 33° to 35° C. (91.4° to 95° F.), which characterized the close of the transition from winter to summer conditions, characterize equally well the prevailing summer phenomena. So constant were the temperatures in summer that their peculiarities may be briefly summarized. Few external factors influenced the hive temperature, and these affected it but slightly. In the original plan of the experiment it was hoped that it would be possible to discover whether there is any correlation between honey flows and temperatures; but inasmuch as the season was excessively dry and the flowers secreted no nectar for weeks at a time, this phase of the experiment could not be carried out.

RELATION OF C TO THE OUTSIDE TEMPERATURE.

Whatever is said of *c* in the following paragraphs applies equally to *b*, and practically as well to all the thermometers in the hive.

Although the temperature at *c* coursed constantly in the opposite direction to *o* during the winter, there is no appreciable correlation between the temperatures in the summer. It might be said of the hive that the temperature as a whole was independent of external conditions. A few exceptions to this will follow, however. During a period of stormy and cooler weather, for instance, although there were slight changes which will be discussed later, the temperatures were largely unaffected. Moreover, since the oscillation of *c* was slight, as will be explained, there was little relationship between the temperature of the center of the cluster and *o*.

THE MAXIMA AND MINIMA OF C IN RELATION TO O.

The daily oscillation between the maximum and minimum of *c* was usually less than 1° C. (1.8° F.), and in many instances it was but one or two tenths of a degree. On the whole the temperature in the brood nest is remarkably constant, ranging between 34° and 35° C. (93.2° to 95° F.).

Even with this slight fluctuation there was perceptible on many days a maximum and minimum for *c*, and particularly for the other hive thermometers which perhaps were the most influenced by external conditions. It may be said that, roughly, the maxima and minima occurred within two hours of the maxima and minima of *o*, but since in some instances this happened previous to the maximum and minimum out of doors, the warming up of the colony due to the increasing activity of the bees must have had its effect.

To show how closely the maxima of the thermometers in the outer parts of the cluster ultimately approached the readings of the central thermometers, it may be said that while in April the maximum of the outer thermometers in the hive was 19° C. (66.2 F.), in the following months it rarely fell below 34° C. (93.2° F.). In September, however, with the general cooling of the atmosphere, it fell to 28° C. (82.4° F.). This showed the tendency at the close of the experiment for the colony to approach winter conditions. The facts show again the unity or equalization of the temperature throughout the cluster, which in the brood-rearing season ranges between 34° and 35° C. (93.2° to 95° F.). The maxima and minima are shown in Table V. The range of the oscillation shows the constancy of the temperature during the height of the season and the greater fluctuations in spring and fall.

TABLE V.—*Maximum and minimum temperatures of the center of the cluster during summer. Thermometer C.*

Month.	Maximum.		Minimum.		Approximate range.	
	° C.	° F.	° C.	° F.	° C.	° F.
April	35.4	95.7	31.6	88.9	4	7.2
May	36.0	96.8	33.8	92.9	2	3.6
June	35.5	95.9	33.6	92.5	2	3.6
July	35.0	95.0	33.2	91.8	2	3.6
August	35.8	96.4	33.8	92.9	2	3.6
September	34.8	94.6	28.0	82.4	7	12.6

FLUCTUATIONS IN THE HIVE TEMPERATURE AND THE CAUSES.

It has already been said that the fluctuations in the hive temperature were slight and that hot days and winds had very slight effect on the cluster temperature. There are some minor fluctuations due to internal and external disturbances which caused decrease or increase in the hive temperature.

THE EFFECT OF "ORIENTATION" OR "PLAY FLIGHTS."

Every beekeeper is familiar with the "play flights" of young bees about noon on warm sunny days. These are generally believed to be "orientation flights," in which the young bees fly forth in circles and with head toward the hive in order to learn its location. During the period of resumed brood rearing in August these flights occurred every few days in the experimental colony. At such times thermometer readings were taken at short intervals. Instead of causing the heat of the hive to increase these flights first caused a decrease, then a slight increase. Table VI presents figures for a typical observation, made after the bees had been confined to the hive by inclement weather for three days.

TABLE VI.—*Effects of "orientation flights" of bees on the temperature of the hive.*

Aug. 28.	Thermometer.													
	a.		*b.*		*c.*		*d.*		*e.*		*f.*		*o.*	
	° C.	° F.	° C.	° F.	° C.	° F.	° C.	° F.	° C.	° F.	° C.	° F.	° C.	° F.
6 a. m.[1]	34.0	93.2	34.4	93.92	34.4	93.92	34.4	93.92	33.6	92.48	34.6	94.28	15.6	60.08
7 a. m.	34.0	93.2	34.4	93.92	34.4	93.92	34.0	93.2	33.4	92.12	34.4	93.92	16.4	61.52
8 a. m.[2]	34.0	93.2	34.2	93.56	34.2	93.56	34.0	93.2	33.4	92.12	34.6	94.28	16.8	62.24
9 a. m.	34.0	93.2	34.0	93.2	34.3	93.74	34.0	93.2	33.2	91.76	34.6	94.28	17.4	63.32
10 a. m.	34.0	93.2	34.2	93.56	34.3	93.74	34.0	93.2	33.2	91.76	34.8	94.64	18.0	64.40
11 a. m.[3]	33.8	92.84	33.8	92.84	33.8	92.84	33.8	92.84	33.2	91.76	34.2	93.56	19.4	66.92
11.30 a. m.[4]	33.8	92.84	34.0	93.2	34.0	93.2	34.0	93.2	33.8	92.84	34.4	93.92	20.0	68.0
12 m.	34.0	93.2	34.0	93.2	34.0	93.2	34.0	93.2	33.6	92.48	34.4	93.92	19.6	67.28
1 p. m.	34.0	93.2	34.2	93.56	34.2	93.56	34.0	93.2	33.6	92.48	34.8	94.64	20.2	68.36
2 p. m.[5]	33.8	92.84	34.0	93.2	34.0	93.2	33.8	92.84	33.6	92.48	34.4	93.92	20.2	68.36
2.15 p. m.	34.0	93.2	34.0	93.2	34.0	93.2	34.0	93.2	33.6	92.48	34.4	93.92	20.4	68.72
2.30 p. m.[6]	34.0	93.2	34.0	93.2	34.2	93.56	34.0	93.2	33.6	92.48	34.6	94.28	20.0	68.0
2.45 p. m.	34.0	93.2	34.2	93.56	34.2	93.56	34.0	93.2	33.8	92.84	34.8	94.64	20.4	68.72
3 p. m.	34.0	93.2	34.2	93.56	34.2	93.56	34.0	93.2	33.8	92.84	34.8	94.64	20.8	69.44
4 p. m.	34.0	93.2	34.4	93.92	34.4	93.92	34.2	93.56	33.8	92.84	34.8	94.64	20.2	68.36

[1] Cloudy.
[2] Bees fly slightly.
[3] First good fly for three days.
[4] Quieted flight.
[5] Bees fly freely again.
[6] Quiet again.

It will be noticed that short flights were taken at 8 o'clock in the morning when the thermometer *c* fell 0.2° C. At 11 o'clock the first flight of importance occurred. Then there was another slight drop in the temperature followed by a rise. At 2 o'clock there was a similar flight and change in the thermometer. In all cases within 15 to 30 minutes the thermometer had regained its normal temperature. While the drop was actually slight, when it is remembered that the daily fluctuation in the temperature was frequently but a fraction of a degree, the decrease was relatively considerable. The same effect was noticed in the spring and in the early part of the season, when the bees first commenced to take field trips. This cooling effect must be attributed to the rushing forth of the bees from the cluster; in so doing they liberate the confined heat of the cluster. Another factor is probably the excessive fanning at the entrance which usually accompanies these "play" flights. When the activities wane and the bees commence to return to the hive, the temperature resumes its normal condition.

A similar decrease in temperature was common in the early morning when the bees commenced to leave the hive for the field. For comparison with the foregoing, the readings taken in the early morning of August 3 and 4 are presented in Table VII.

TABLE VII.—*Effects of early morning flight of bees on temperature of the hive.*

Date.	Thermometer.											
	a		*b*		*c*		*d*		*e*		*o*	
	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*
Aug. 3.												
8 a. m.	34.0	93.2	34.2	93.56	34.6	94.28	34.2	93.56	34.0	93.2	22.6	72.68
9 a. m.	33.8	92.84	34.2	93.56	34.4	93.92	34.2	93.56	33.8	92.84	26.0	78.80
10 a. m.	33.9	93.02	34.4	93.92	34.8	94.64	34.2	93.56	34.0	93.2	26.8	80.24
11 a. m.	34.0	93.2	34.4	93.92	34.8	94.64	34.6	94.28	34.0	93.2	27.4	81.32
12 m.	34.0	93.2	34.6	94.28	34.8	94.64	34.6	94.28	34.0	93.2	28.0	82.40
Aug. 4.												
5 a. m.[1]	34.4	93.92	34.6	94.28	34.8	94.64	34.6	94.28	34.2	93.56	21.2	70.16
6 a. m.	34.4	93.92	34.6	94.28	34.6	94.28	34.6	94.28	34.4	93.92	21.0	69.80
7 a. m.[2]	34.0	93.2	34.4	93.92	34.6	94.28	34.2	93.56	34.0	93.2	22.6	72.68
8 a. m.	34.0	93.2	34.4	93.92	34.8	94.64	34.4	93.92	34.0	93.2	25.0	77.00
9 a. m.	34.0	93.2	34.8	94.64	34.8	94.64	34.4	93.92	34.0	93.2	27.0	80.60

[1] Fanning entrance. [2] Bees begin to fly freely.

EFFECTS OF CLUSTER HEAT ON THE TEMPERATURE BELOW THE FRAMES.

It was found that the heat from the cluster had no perceptible influence on the temperature of the air below the frames during the winter. Practically the air was at the outside temperature. But in summer totally different conditions prevail; the temperature within the hive becomes equalized. Furthermore, the crowding of the bees at certain seasons tends to force them to hang down from the bottoms of the frames or even out at the entrance. Consequently that space which was outside the frames assumes cluster conditions.

Early in the season *f* averaged 3° C. higher than *o* at all times; at the end of the season, September, it averaged from 5° to 6° C. higher. By the middle of May *f* stood only 1° or 2° C. lower than the thermometers in the cluster, although the thermometer in the outside air was much lower. Throughout the summer there was practically no difference between *c* and *f*. During the storm period, as will be seen in Table IX, which is discussed farther on, *f* ranged even higher than the prevailing cluster temperature. This was undoubtedly due to the massing of the bees below the frames as they were crowded in from the alighting board.

THE EFFECTS OF STORM.

Since the summer of 1908 was remarkably dry and free from storms, it is not possible to draw any definite conclusions upon the effects of storms, cold waves, and winds upon the cluster temperature. The only severe storm of the summer occurred in the latter part of August. The outside thermometer went as low as 14° C. (57.2° F.), while before and after this period there were frequent readings ranging from 20° to 30° C. (68° to 86° F.). During the storm there were several high winds. These, however, did not blow directly in at the entrance. The bees were thus confined for three days, and at times showed much evidence of shifting and massing at different parts of the hive. In a glass observatory hive the bees were actually seen to cluster now in one part of the hive and then in another. The wind and rain also drove the bees in off of the alighting board and forced them to hang from the bottoms of the frames. If the readings of the thermometers nearest the outside of the hive are rightly interpreted, the cluster withdrew from the walls of the hive, and this caused a decrease in the temperature at these points. While there is some evidence in the figures that the cold outside the hive had its effects on the center of the cluster, the temperature was not permitted to remain below 34° C. (93.2° F.). No fall was recorded lower than 33.8° C. (92.84° F.). Thus the bees appear to be able to control and conserve the temperature with remarkable constancy, even though there be high wind and relatively low temperature. Table IX, in comparison with the figures for a bright day in Table VIII, reveal these facts.

TABLE VIII.—*Temperatures of a bee colony on a normal day.*

Time.		Thermometer.											
Month and day.	Hour.	*a.*		*b.*		*c.*		*d.*		*e.*		*o.*	
		°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*
Aug. 15	6 a. m.[1]	34.4	93.92	34.4	93.92	35.0	95.00	34.8	94.64	34.8	94.64	24.4	75.92
	7 a. m.	34.4	93.92	34.4	93.92	34.8	94.64	34.8	94.64	34.6	94.28	26.0	78.80
	8 a. m.	34.2	93.56	34.4	93.92	34.8	94.64	34.8	94.64	34.8	94.64	24.6	76.28
	9 a. m.[2]	34.2	93.56	34.4	93.92	34.8	94.64	34.8	94.64	34.8	94.64	25.8	78.44
	10 a. m.	34.6	94.28	34.6	94.28	34.8	94.64	34.6	94.28	34.6	94.28	27.6	81.68
	11 a. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	28.8	83.84
	12 m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	29.0	84.20
	1 p. m.	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	35.0	95.00	29.6	85.28
	2 p. m.	35.0	95.00	35.0	95.00	35.0	95.00	35.2	95.36	35.2	95.36	30.4	86.72
	4 p. m.	35.0	95.00	35.0	95.00	35.0	95.00	35.2	95.36	35.2	95.36	29.2	84.56
	6 p. m.	35.0	95.00	35.0	95.00	35.2	95.36	35.2	95.36	35.2	95.36	28.2	82.76
	7 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.2	95.36	35.0	95.00	27.6	81.68
	8 p. m.	35.0	95.00	35.0	95.00	35.0	95.00	35.0	95.00	35.0	95.00	26.6	79.88
Aug. 18	6 a. m.	34.0	93.2	34.2	93.56	34.0	93.2	34.0	93.2	34.2	93.56	21.8	71.24
	7 a. m.[3]	34.2	93.56	34.2	93.56	34.4	93.92	34.4	93.92	34.2	93.56	22.0	71.60
	8 a. m.	34.2	93.56	34.2	93.56	34.4	93.92	34.4	93.92	34.2	93.56	22.4	72.32
	9 a. m.[4]	34.4	93.92	34.4	93.92	34.6	94.28	34.6	94.28	34.4	93.92	25.0	77.00
	10 a. m.[5]	34.4	93.92	34.6	94.28	34.6	94.28	34.8	94.64	34.6	94.28	26.0	78.80
	11 a. m.	34.6	94.28	34.8	94.64	34.8	94.64	34.8	94.64	34.8	94.64	26.5	79.70
	12 m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	27.4	81.32
	1 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	28.6	83.48
	2 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	29.0	84.20
	3 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	28.0	82.40
	4 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.2	95.36	35.2	95.36	28.0	82.40
	6 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.2	95.36	27.4	81.32
	7 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	26.2	79.60
	8 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	35.0	95.00	35.0	95.00	25.6	78.08

[1] Cloudy and calm.
[2] Clearing, calm and close.
[3] Cloudy.
[4] Clearing and calm.
[5] Clear.

TABLE IX.—*The effects of storm and wind on the temperatures of the bee colony.*

Time.		Thermometer.													
		a.		*b.*		*c.*		*d.*		*e.*		*f.*		*o.*	
Month and day.	Hour.	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*
Aug. 25	8 a. m.[1]	34.2	93.56	34.4	93.92	34.2	93.56	34.2	93.56	34.0	93.20	34.6	94.28	20.4	68.72
	8.30 a. m.	34.2	93.56	34.2	93.56	34.2	93.56	34.2	93.56	34.0	93.20	34.6	94.28	19.8	67.64
	9 a. m.[2]	34.4	93.92	34.4	93.92	34.2	93.56	34.2	93.56	33.8	92.84	34.6	94.28	19.8	67.64
	10 a. m.	34.0	93.20	34.2	93.56	34.2	93.56	34.2	93.56	34.0	93.20	34.6	94.28	20.8	69.44
	11 a. m.[3]	34.2	93.56	34.4	93.92	34.4	93.92	34.2	93.56	34.0	93.20	34.6	94.28	20.2	68.36
	12 m.	34.0	93.20	34.8	94.64	34.2	93.56	34.4	93.92	34.0	93.20	34.6	94.28	20.6	69.08
	1 p. m.[4]	34.2	93.56	34.4	93.92	34.2	93.56	34.2	93.56	34.0	93.20	34.6	94.28	18.4	65.12
	2 p. m.	34.0	93.20	34.6	94.28	34.0	93.20	34.0	93.20	34.4	93.92	34.6	94.28	17.8	64.04
	3 p. m.	34.0	93.20	34.4	93.92	34.2	93.56	34.2	93.56	34.0	93.20	34.6	94.28	17.6	63.68
	4 p. m.	34.0	93.20	34.8	94.64	34.2	93.56	34.0	93.20	34.0	93.20	34.6	94.28	17.0	62.60
	5 p. m.	34.0	93.20	34.0	93.20	34.2	93.56	34.0	93.20	34.0	93.20	34.6	94.28	16.2	61.16
	6 p. m.[4]	34.0	93.20	34.2	93.56	34.0	93.20	34.0	93.20	33.6	92.48	34.6	94.28	18.2	64.76
	7 p. m.	34.0	93.20	34.4	93.92	34.2	93.56	34.2	93.56	33.6	92.48	34.6	94.28	16.4	61.52
	8 p. m.	33.8	92.84	34.2	93.56	34.2	93.56	34.0	93.20	33.4	92.12	34.6	94.28	16.2	61.16
	9 p. m.	34.0	93.20	34.2	93.56	34.2	93.56	34.0	93.20	33.6	92.48	34.6	94.28	15.0	59.00
	10 p. m.	34.0	93.20	34.4	93.92	34.4	93.92	34.4	93.92	33.0	91.40	34.6	94.28	15.0	59.00
	11 p. m.	34.0	93.20	34.2	93.56	34.4	93.92	34.2	93.56	33.2	91.76	34.6	94.28	14.6	58.28
	12 p. m.	33.8	92.84	34.0	93.20	34.2	93.56	34.0	93.20	33.4	92.12	34.6	94.28	15.4	59.72
Aug. 26	1 a. m.	33.8	92.84	34.2	93.56	34.0	93.20	34.0	93.20	33.4	92.12	34.6	94.28	15.6	60.08
	2 a. m.	33.6	92.48	34.0	93.20	34.0	93.20	34.2	93.56	33.0	91.40	34.6	94.28	14.8	58.64
	3 a. m.[5]	33.6	92.48	34.2	93.56	34.2	93.56	34.0	93.20	33.4	92.12	34.6	94.28	17.4	63.32
	4 a. m.[6]	33.6	92.48	34.2	93.56	34.2	93.56	34.0	93.20	33.4	92.12	34.6	94.28	16.2	61.16
	5 a. m.[6]	33.6	92.48	34.0	93.20	34.2	93.56	34.0	93.20	33.2	91.76	34.6	94.28	17.0	62.60
	6 a. m.[6]	33.6	92.48	34.2	93.56	34.2	93.56	34.0	93.20	33.2	91.76	34.6	94.28	16.6	61.88
	7 a. m.[6]	33.6	92.48	34.4	93.92	34.2	93.56	33.6	92.48	33.4	92.12	34.6	94.28	17.0	62.60

[1] Cloudy.
[2] Breeze from north.
[3] Raining a little.
[4] Rain.
[5] High wind from east.
[6] High wind from east, no rain.

Another fact to which reference has been made under the caption, "Effects of cluster heat on the temperature below the frames," should be mentioned here. During this period of storm, *f* frequently recorded a higher temperature than the thermometers above it. This was undoubtedly due to the crowding of the bees in off of the alighting board, forming a curtain below the frames. This is an advantage in helping to conserve the heat and in preventing the cold, inward draft through the entrance from striking directly on the brood.

THE EFFECTS OF TRANSPORTATION ON THE TEMPERATURE OF THE COLONY.

Not infrequently beekeepers sustain heavy losses in moving their bees, although it is not usually done in extremely hot weather. Since the moving of the experimental colony to College Park, Md., a distance of about 11 miles, was unavoidable, the writer decided to make the most of the necessity and determine in so far as possible the effects of transportation on the colony. Even with precautions, strong and populous colonies sometimes smother. Brood is often killed, supposedly from excessive heat. With these points in mind every precaution was taken to protect the colony from harm; and since no damage resulted, the experiment reveals the temperature conditions in a successful transportation of a strong colony under most adverse circumstances—extreme heat and humidity and bad roads.

The trip was commenced at 10.30 a. m. on July 2. The day was humid, with intermittent sunshine and clouds, and no breeze. In Washington the mercury rose to 32.33° C. (90° F.) at 2 o'clock. The road was through the city of Washington over asphalt and stone pavements for several miles and then over rough country roads, which had scarcely any shade. The colony was moved on a spring express wagon with cover, the curtains of which were kept down on the sunny side so as to prevent the sun from striking directly on the hive. The other curtains were rolled up in order to allow all the ventilation possible, but since there was no breeze all the draft which the bees got must have been procured by fanning and by the movement of the wagon.

The colony was crowded into a 10-frame Langstroth hive and the entrance was screened the night previous. All of the thermometers remained in position. This, of course, prevented giving ventilation through the top of the hive, which is the common practice in moving bees. In order to give room for expansion of the cluster and to confine the air as little as possible, the hive was set over an empty body, on the bottom of which wire cloth was tacked. In order to allow the air to circulate freely beneath the hive, it was supported above the bottom of the wagon on $\frac{7}{8}$-inch strips of wood, the spring of which relieved to some extent the jolt of the wagon. In the morning, before the colony was disturbed and just after it was loaded, thermometer readings were taken. On the road readings were also made at short intervals. In this way the result of every successive event in the trip was known.

The first disturbance, carrying the hive downstairs and loading, was immediately responded to by the bees. The first 15 minutes on the road were but slightly more disturbing. Gradually, however, the temperature increased until 1.30 o'clock in the afternoon and an hour previous to releasing, when practically the maximum was reached, 36.0° C. (96.8° F.). It should be mentioned, however, that during the next few hours and even after the bees had their liberty the thermometers in the distant parts of the hive, *a* and *e*, registered 36.2° C. (97.16° F.). But it is probable that the bees clustered more densely at these points than they did in the center of the hive. This temperature can not be considered particularly abnormal, although it is higher than any temperature registered immediately before or after the transportation. On several occasions during the summer and even in May, practically the same degree was reached; but since in normal circumstances it never went higher than 36° C. (96.8° F.), the temperature observed is probably nearly as high as can be reached by bees without damage. It would not have taken many degrees more than this to have softened the combs and to have caused them to sag and break. The melting point of pure wax is 62° to 64° C. (143° to 145° F.), but the difference between the melting point and the point at which combs become soft enough to sag must be considerable, perhaps 20° C. (36° F.).

It can not be said that the temperature was higher at any one part of the hive than at another, unless possibly there was a slight tendency for the brood cluster to be maintained cooler. This would naturally be expected, but under such trying circumstances the phenomenon could not be measured satisfactorily. At no time on the trip did the bees hang down from their combs into the lower body, and upon releasing them there was no evidence of condensation. At all times, as would have been expected, there was considerable fanning. Furthermore, the bees were not made cross by their confinement, as was the case when the rest of the colonies of the apiary were moved, which was done under much more favorable circumstances except for ventilation. That no brood died in the experimental colony is further evidence that 36° C. (96.8° F.) is not abnormal.

The colony was placed in its new position at 2.30 o'clock and the bees liberated. The effects of their liberty on the temperatures were not apparent, however, as will be seen in Table XI, for more than an hour, when the temperatures began gradually to fall. Finally, when the bees had orientated themselves and had commenced to return to the hive, there was a noticeable quieting and a perceptible drop in the mercury. At 7.30 o'clock, after all the bees had returned to the hive, conditions were practically normal.

In conclusion it may be said that the conditions under which the bees were moved, although trying and about as adverse as possibly could be encountered, did not produce abnormal heat in the hive. The temperature increased only 2°, from 34° to 36°+C. (93.2 to 96.8° F.). While it is generally admitted that ventilation from the top is preferable in moving bees, on the hypothesis that warm air rises, ventilation from the bottom was a success in the case under discussion. In moving the rest of the department apiary to College Park earlier in the season, when the weather was more favorable, the day being cloudy with showers, three colonies suffered severely from overheating and condensation. These colonies were screened at the entrance and over the top of the hive; but apparently the screening of the top was not sufficient, because when the bees became excited and expanded as a result of the heat, they packed so tightly against the top screen as to shut out all ventilation. The tendency of bees is upward and toward the light. On the contrary, if ventilation is given from below, there is less tendency for them to pack against the screen. While it is generally maintained that for moving colonies top ventilation is preferable, the present experiment would indicate that bottom ventilation is practical and advantageous.

For comparison, figures taken the day previous (Table X) and the day after the transportation (Table XII), as well as on that day (Table XI), are presented.

TABLE X.—*Readings of thermometers, July 1, on day previous to transportation of bee colony.*

Hour.	Thermometer.											
	a.		*b.*		*c.*		*d.*		*e.*		*o.*	
	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*
9 a. m.	33.4	92.12	34.0	93.20	34.0	93.20	33.8	92.84	33.8	92.84	25.8	78.44
10 a. m.	33.6	92.48	34.0	93.20	34.2	93.56	33.6	92.48	33.6	92.48	27.0	80.60
11 a. m.	33.8	92.84	34.2	93.56	34.2	93.56	33.8	92.84	33.6	92.48	28.5	83.30
12 m.	33.9	93.02	34.5	94.10	34.5	94.10	33.9	93.02	33.9	93.02	29.0	84.20
1 p. m.	34.0	93.20	34.5	94.10	34.5	94.10	34.0	93.20	34.0	93.20	29.8	85.64
2 p. m.	34.4	93.92	34.8	94.64	34.8	94.64	34.0	93.20	34.0	93.20	31.5	88.70
3 p. m.	34.4	93.92	34.8	94.64	34.8	94.64	34.0	93.20	34.0	93.20	31.5	88.70
4 p. m.	34.6	94.28	34.8	94.64	34.8	94.64	34.2	93.56	34.2	93.56	32.2	89.96
8 p. m.	34.8	94.64	34.8	94.64	35.0	95.00	34.8	94.64	35.0	95.00	29.0	84.20

TABLE XI.—*Readings of thermometers during transportation of bees, July 2. Day extremely warm and sultry.*

Hour.	Thermometer.										Observations.
	a		*b*		*c*		*d*		*e*		
	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	
9 a. m.	34.4	93.92	34.4	93.92	34.4	93.92	34.0	93.20	34.0	93.20	Hive closed but unmoved.
10.15 a. m.	35.0	95.00	35.0	95.00	35.0	95.00	34.8	94.64	34.8	94.64	Hive loaded on wagon.
10.30 a. m.	35.0	95.00	35.0	95.00	35.0	95.00	34.8	94.64	34.8	94.64	Drive to College Park started.
10.45 a. m.	35.2	95.36	35.0	95.00	35.1	95.18	34.9	94.82	35.0	95.00	
11 a. m.	35.4	95.72	35.2	95.36	35.2	95.36	35.0	95.00	35.0	95.00	
11.15 a. m.	35.4	95.72	35.0	95.00	35.1	95.18	35.0	95.00	35.0	95.00	Sun and clouds.
11.30 a. m.	35.6	96.08	35.2	95.36	35.2	95.36	35.0	95.00	35.0	95.00	Do.
11.45 a. m.	35.8	96.44	35.4	95.72	35.6	96.08	35.1	95.18	35.2	95.36	Do.
12 m.	35.8	96.44	35.6	96.08	35.6	96.08	35.3	95.54	35.4	95.72	Do.
12.15 p. m.	35.8	96.44	35.8	96.44	35.6	96.08	35.4	95.72	35.6	96.08	Do.
12.45 p. m.	35.8	96.44	35.6	96.08	35.6	96.08	35.4	95.72	35.6	96.08	Stopped 30 minutes for lunch.
1 p. m.	35.8	96.44	35.6	96.08	35.6	96.08	35.6	96.08	35.6	96.08	
1.15 p. m.	36.0	96.80	35.8	96.44	35.8	96.44	35.8	96.44	35.8	96.44	
1.30 p. m.	36.0	96.80	36.0	96.80	35.9	96.62	35.8	96.44	36.0	96.80	
2 p. m.	36.0	96.80	36.0	96.80	36.0	96.80	35.9	96.62	36.0	96.80	
2.30 p. m.	36.2	97.16	36.0	96.80	36.0	96.80	36.0	96.80	36.1	96.98	Hive set on stand and opened.
3 p. m.	36.2	97.16	36.0	96.80	36.0	96.80	36.0	96.80	36.2	97.16	
3.30 p. m.	36.2	97.16	35.8	96.44	35.8	96.44	36.0	96.80	36.0	96.80	
4 p. m.	36.1	96.98	35.4	95.72	35.8	96.44	36.0	96.80	36.0	96.80	
4.30 p. m.	35.4	95.72	34.1	93.38	34.8	94.64	35.1	95.18	35.4	95.72	
5 p. m.	35.0	95.00	34.0	93.20	34.6	94.28	34.9	94.82	35.0	95.00	
6.30 p. m.	34.6	94.28	34.2	93.56	34.2	93.56	34.4	93.92	34.4	93.92	Bees all returned to hive.
7 p. m.	34.4	93.92	34.2	93.56	34.2	93.56	34.2	93.56	34.2	93.56	
7.30 p. m.	34.4	93.92	34.0	93.20	34.0	93.20	34.2	93.56	34.2	93.56	Quiet and normal.

TABLE XII.—*Readings of thermometers, July 3. Day after transportation of bees.*

Hour.	Thermometer.										Observations.
	a		*b*		*c*		*d*		*e*		
	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	°*C.*	°*F.*	
7.30 a. m.	33.8	92.84	34.0	93.20	34.0	93.20	33.6	92.48	33.0	91.40	
8.30 a. m.	33.8	92.84	33.8	92.84	34.0	93.20	33.4	92.12	33.0	91.40	Cloudy.
10 a. m.	33.8	92.84	34.0	93.20	34.0	93.20	33.4	92.12	33.6	92.48	Breeze.
11 a. m.	34.0	93.20	34.0	93.20	34.0	93.20	33.4	92.12	33.4	92.12	
12 m.	34.0	93.20	34.2	93.56	34.2	93.56	33.6	92.48	33.4	92.12	
7 p. m.	34.8	94.64	34.8	94.64	34.6	94.28	34.2	93.56	34.0	93.20	Bees returned.
8 p. m.	34.8	94.64	34.6	94.28	34.6	94.28	34.0	93.20	34.0	93.20	

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