Langstroth Bee Hive Internal Temperature Variations

Method

Temperatures were recorded over various time intervals by using 4 temperature recording devices with probes inserted through a hole drilled into the supers or baseboard at various places in the hive. The probes were fed through a plastic tube (to prevent the bees chewing the lead in wire) but with an open end for the probe tip. The probes could be positioned anywhere in the horizontal plane through to approximately the super centre. Three probes were used to measure internal temperatures and one to measure the ambient temperature.

In this 4 box (1 brood and 3 supers) hive, a “slatted rack” was used between the base board and the brood box. It keeps a bee space below the brood box and the “rack” but allows for about 50mm space between the “rack” and the base board. The bees do not build burr comb below this “rack”. Its main purpose is to provide extra space above the base board for bees to move about and may help in hive ventilation control. I do not think it makes any significant difference to the measurements as they are all made above this “rack”.

The hive is fitted with an inner cover (I happen to use thick glass to allow observation) allowing a bee space above the top frames. This inner cover has two small screened top vent slots (10mm by 100mm) that can be blocked as required (over wintering). An extra “linoleum” sheet is placed over the inner cover to help prevent loss of heat through the inner cover over winter.

The hive top telescopic cover leaves about 60mm space above the inner cover and has two small vents in the sides.

Probe positioning

The probes were inserted:

- Below brood box
  in the bee space just between the brood box frames and the slatted rack.
- Above first honey super
  in the second honey super in the bee space below the frame bottoms.
- Above second honey super
  in the third honey super in the bee space below the frame bottoms.

Measurement Periods

Comparisons were made with the top vents open and closed.

Summer 2016 (1 brood box and three supers)

24 feb to 3 march 2016 - **no top vents**
high humidity - ambient between 20 to 35 degrees C.
15 to 23 march 2016 - **top vents open**
high humidity - ambient between 16 to 26 degrees C.
(**** note** probes repositioned to box sides - see below)

27 march to 6 april 2016 - **top vents open**
high humidity - ambient between 17 to 30 degrees C.
8 to 10 april 2016 - **base board cavity**
high humidity - ambient 20 to 28 degrees C.

Winter 2016 (hive reduced to 1 brood box and 2 supers)

16 to 29 june 2016 - **no top vents**
low humidity - ambient between 4 to 25 degrees C.
2 to 9 july 2016 - **top vents open**
low humidity - ambient between 4 to 23 degrees C.
12 to 21 july 2016 - **top vents open**
low humidity - ambient between 0 to 30 degrees C.

**** note**
For the summer period 15 to 23 march, the probes were re-positioned. The one below the brood box and the one above the first honey super were withdrawn so as to measure the temperature adjacent to the side of the box and not the centre.

It was thought it may indicate a cyclic flow of cooling air down the sides of the hive.

Base Board Cavity

The probes were inserted :

1. in the bee space just below the brood box frames and the slatted rack.
2. through the centre of the base board rear riser with the probe tip approx. 100mm inside the base board cavity.
3. through the front side of the base board riser such that the probe tip was situated in the base board cavity between the two hive entrances and approx. 50mm inside the entrance. (two standard hive entrance slots existed on this hive)

These measurements were made to see what was happening in the base board cavity - the base board had a tin bottom with beetle trap fitted. The overall base board cavity was effectively increased because of the “slatted rack” situated on top of the standard size base board.

Notes

-
- The effects of ambient relative humidity are unknown. However, as hive humidity plays an important part in hive ventilation, some comments on the results will hypothesise on how the bees reaction to humidity may play a part.
- The bees will sometimes propolise the top vents. “open top vents” may also include up to 40% propolisation during the tests but there was still some remaining vent action.
- In all tests, there was a consistent temperature gradient from bottom (highest temperature) to the top (lowest temperature) of the hive. The temperature of the cluster was not measured and is assumed to be around the 33 to 36 degrees C mark. The temperature just below the brood frames is around 35 degrees C during summer and around 30 degrees C during winter.

- The high temperatures (at or near cluster temperature) below the brood frames was unexpected if the heated air from the cluster moved upward by convection to be replaced by cooler air in the entrance cavity. Something else appears to be happening.

Observations

With an expected convection forced air flow around the hive, I would have reasoned that the temperature below the brood box would be much lower than cluster temperatures - this is not the case. The temperature above the first honey super is consistently about 5 degrees cooler than below the brood box. The temperature above the second honey super is consistently even cooler again which could be partly attributed to evaporative cooling of the honey but again unexpected.

The gradual cooling of the air in the upper regions of the hive could be because of heat loss to the mass of the honey frames and hive walls, and influenced by evaporation of open honey cells. It does indicate a convection forced air flow in the hive but the high temperatures below the brood frames appears to be a contradiction.

As the average ambient temperature drops, all temperatures drop but at a much lower rate, but the temperature measured below the brood box is maintained at above 25 degrees C even when the ambient drops to 0 - and this is just cm's from the open hive entrance.

In both summer and winter, top vents did had a small effect on cooling the hive but only by a few degrees. Of course, these measurements give no indication of any extra "heating" activity that had to be carried out by the worker bees to maintain the hive heat.

In the case where the temperature at the sides of the hive were made, the temperature did drop by around 5 degrees but did not indicate to me that there was significant downward airflow of cool air at the sides. The temperature variation could be simply conduction loss through the box sides.

The base board cavity results are interesting. It is difficult to imagine why the temp in the cavity is significantly higher than the ambient at the peaks. The ambient peaks of course would indicate daylight hours and a period when activity is highest with many bees moving through the cavity. At night, the cavity may be almost empty of bees. Possibly the bees carry hive heat with them as they move through the cavity or cause a downward movement of hive heat.

Conclusions

Hive climate control

From various studies (I acknowledge all sources) :

- Bees have receptors that can detect temperature, humidity, and high levels of carbon dioxide (but not oxygen levels).
- The relative humidity (RH) in the brood nest area of a heathy colony is kept relatively constant at about 50% to 60%. A small diagram below indicates that by fanning, the bees can indeed control the hive RH (ref publicly available). I also note that the SHB

requires high humidity (above 50%) for the eggs to hatch which would help explain the increase in SHB damage in the summer period in this apiary location.

- The brood cells are kept at a much higher humidity - 70-95%.
- Eggs require a RH of above 55% to hatch successfully with no hatching at a RH of much below 50%.
- Established larval cocoons are hygroscopic and the silk lining of the brood cells plays an important part in maintaining the differing humidity requirements. The brood cells may also act as a "dehumidifier" to a certain extent by "soaking" up water vapour from the air and may help the bees to reduce RH in the hive. Old brood cells may be very beneficial to the hive and not something to be "replaced".
- Although carbon dioxide is heavier than air, the bee movement and activity within the hive would not allow separation and the CO2 mix would remain constant (as in the atmosphere)
- The brood temperature is maintained at around 35 degrees. The bees can provide additional heat through metabolic burning of stored honey, and by the use of evaporative cooling highly dependent on air movement maintained by bee movement and internal and external "fanners".

Ventilation

I have read two variations related to how the bees ventilate the hive.

Method 1.

Is where there is a "cycle" of air in the cavity below the brood box, the flow of which is bi-directional at the entrance - cooler fresh air into the hive at the lower level of the entrance, and stale warmer air flowing out at the upper level of the entrance. The air inside the hive is slowly "mixed" with this circulation of air aided by internal bee movement, slow cyclic convection airflow, and fanning.

The convectional airflow around the hive, if at all present, is very low, mainly because of the lack of open air space as the bees in a strong hive will almost fill every cavity and their constant movement will interrupt any natural airflow. They do however keep all the air in the hive "moving" about. Observations also indicate continual movement of bees throughout the hive.

method 2.

Another is where the hive is said to "breath" as one entity. The expiration is active (by fanning), and the inspiration passive (no fanning) The bees will fan internally such that air is directed out of hive perhaps creating a small pressure difference, and then periodically the fanning stops and there is an inflow of fresh air. This is a periodic process and during very hot conditions or suffering excessively high humidity, the bees will fan outside to help the process. Apparently there are both short and longer cycles to this process.

One has to wonder how the bees know the physics of the required fanning direction. I found a reference to an experiment that indicated that the bees will align themselves with their head away from the light (the entrance being the light for internal "fanners"). In an experiment the light source was moved and it was found that the bees indeed realigned. What happens with external "fanners" remains a mystery although they may be simply aligning their heads toward the darker hive entrance.

It may be that during my temperature measurements, by reacting to high humidity

levels or high CO2 levels, the bees are indeed causing a light airflow down toward the entrance. It would help explain the high temperature below the brood frames. Over the measuring period it does not appear that the ambient temperature alone would be high enough to stimulate an active hive ventilation process.

Winter measurements show very low ambient temperatures. It would be difficult to imagine the bees undertaking any cooling during this period. However, they still have to replace stale air. I would imagine that "**method 2"** above would lend itself to this task and indeed I have observed what looks like external entrance fanning even during this colder period.

One thing that seems evident is that the heat loss through a tin base board does not adversely affect internal temperatures to any great degree. In fact, I have a horizontal hive with 60% of the base fitted with an open screen mesh. The bees do not seem to have any problem with this. Indeed, having only a single horizontal layer of frames to contend with (as in nature), it may be much easier for them to control hive temperature and humidity.

With open screen bottoms, it would seem that "method 2" would not work. Even during summer days of very high temperatures (40 degrees C plus) these hives showed no sign of "bearding" where the standard Langstroth hives did. I have read that "bearding" may not be because of high temperatures alone but more of an action to overcome the effects of excessive hive humidity (an interesting article on hive humidity can be found at *http://www.hunter-valley-amateur-beekeepers.org/wp-content/uploads/2016/08/constructive-beekeeping-modified.pdf*).

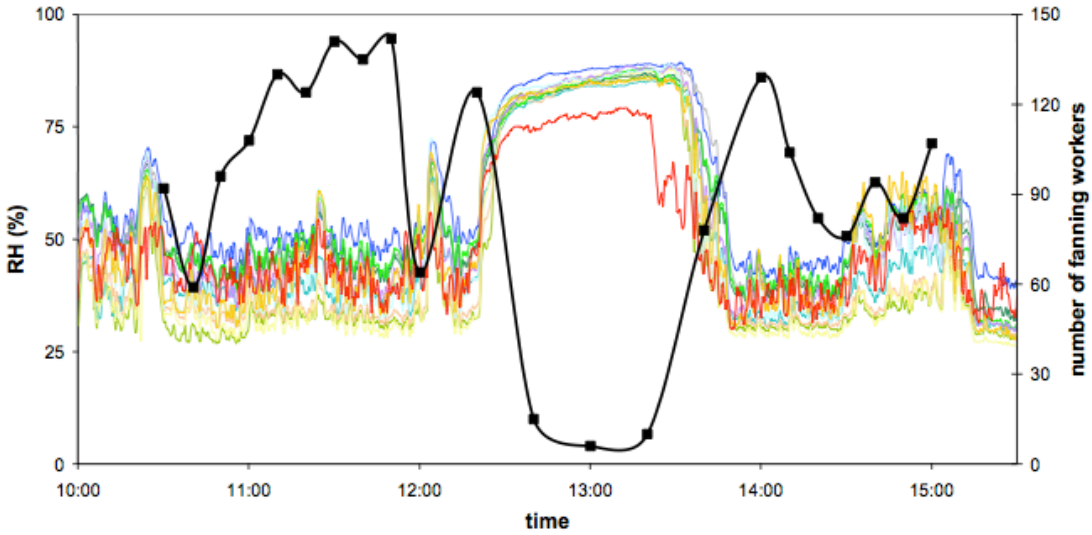
Maybe the bees employ a combination of both methods with their primary instinctive being to move and "mix" any stale air with any available fresh air source. That is, if fresh air is available, they simply use it - if not, they attempt to obtain it (with the help of a few smart instincts)

However, it is unknown if any loss of heat with screen bottoms, or by using top vents, simply caused the bees to work harder (and waste resources) to overcome any heat loss. In my horizontal hive, the honey production is as good as, if not better than the standard hives. I have not observed external entrance fanning, nor bearding in hot weather with these hives. The open base would seem to afford plenty of scope for internal climate control.

The attached graphs are for the reader to interpret for themselves.

Humidity control.

Ref Homeostasis: Humidity and water relations in honeybee colonies (Apis mellifera) Michael B. Ellis 2008.

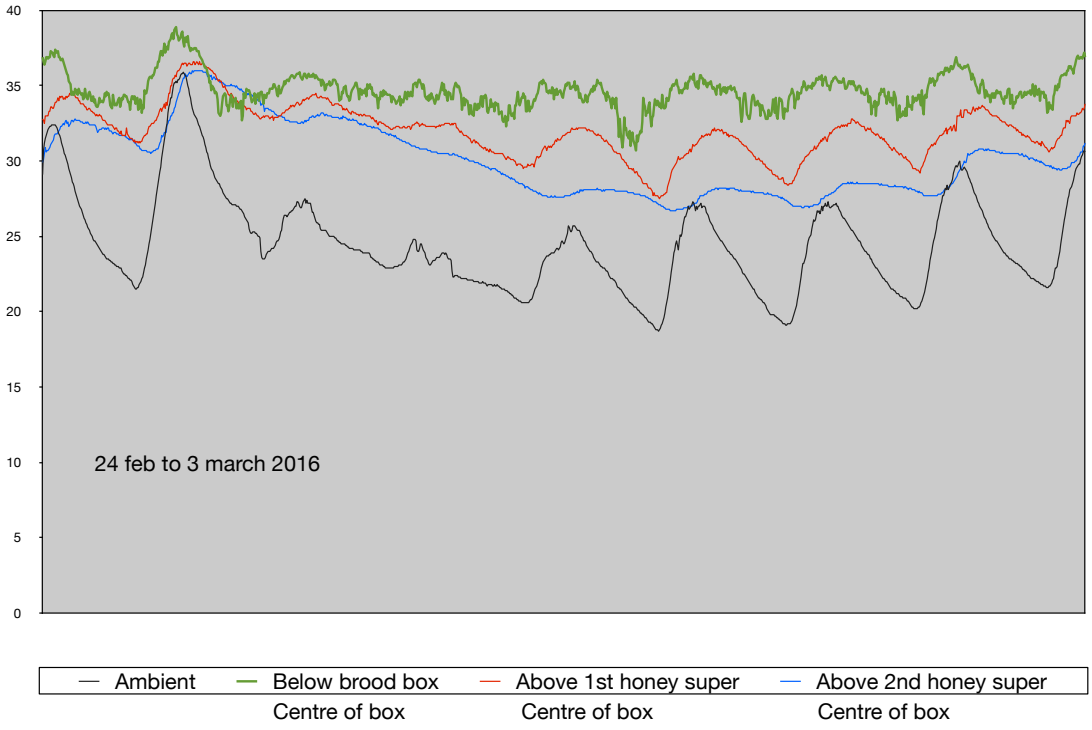


An example of a 3 h experimental run at a room temperature of 35 C and with a flow of 90 % RH air into the top of the hive at 15 litres/minute. This 90 % RH air started flowing into the hive at 10.30 and stopped at 1500 and the fanning workers at the entrance noted between these times.

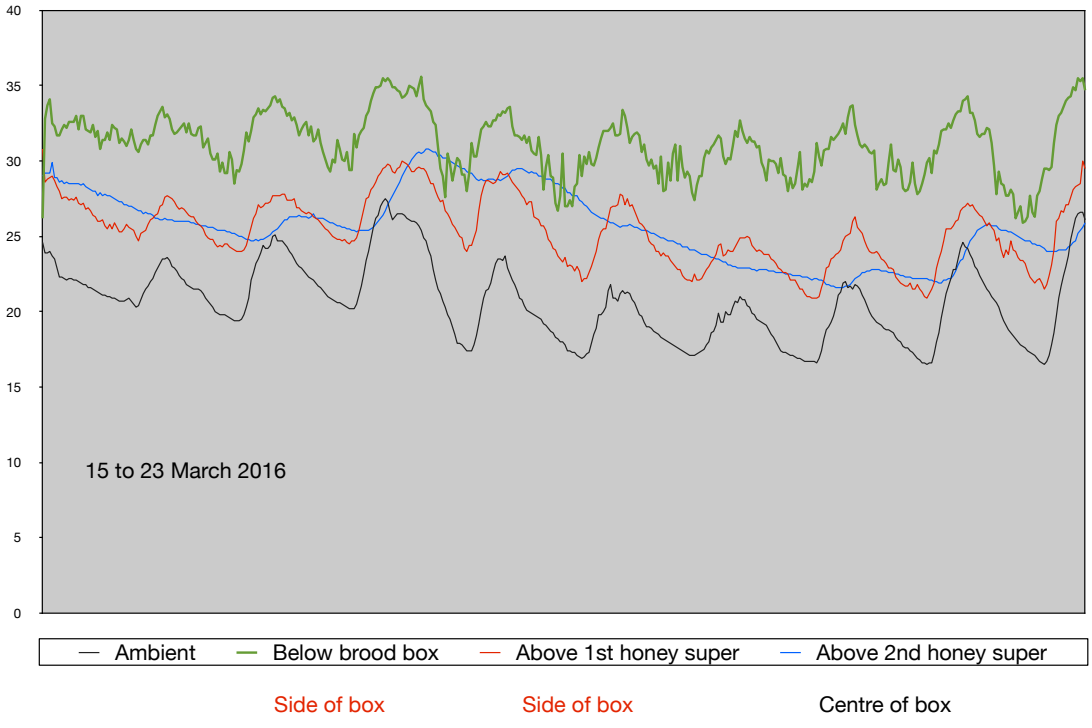
This particular run shows an abnormal response during which the workers stopped fanning for over an hour (12:30 pm to 13:30 pm). The reason for the cessation of fanning is unclear but it caused hive RH to immediately increase to 80% RH. Humidity recordings were obtained by eleven humidity probes (colour lines) placed in the observation hive and the number of fanning workers (black line) was determined by observation.

Note that the bees maintained the internal RH of the hive at around 50% average by fanning with the results of no fanning obvious.

Summer - no top vents **(brood plus 3 super hive with insulated plywood inner cover)**



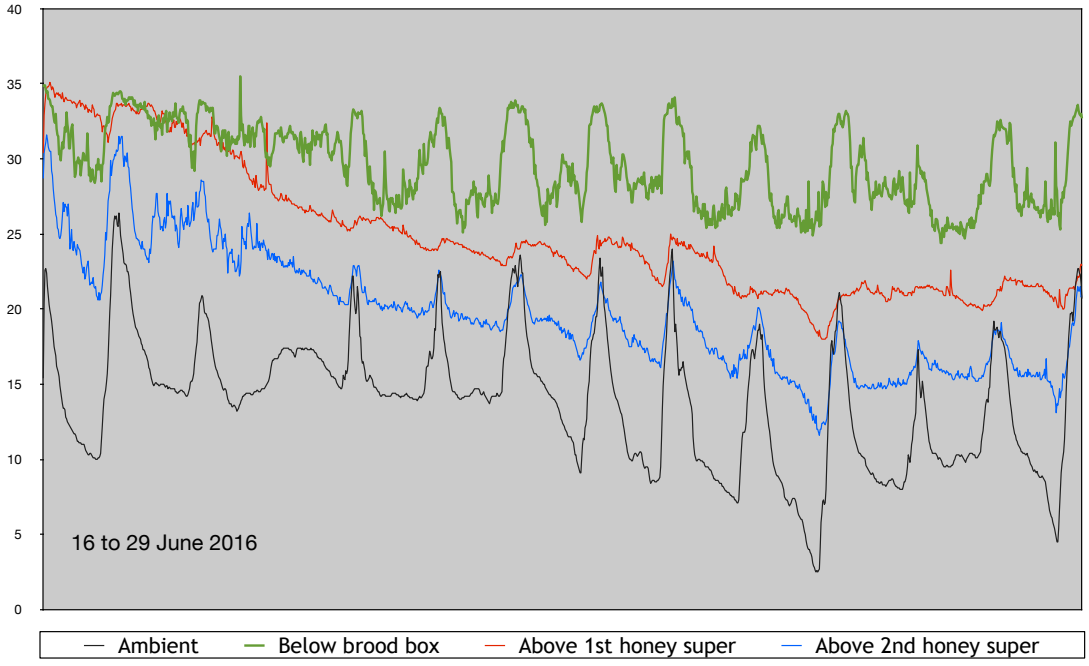
Summer - top vents **(brood plus 3 super hive with insulated plywood inner cover + vents)**



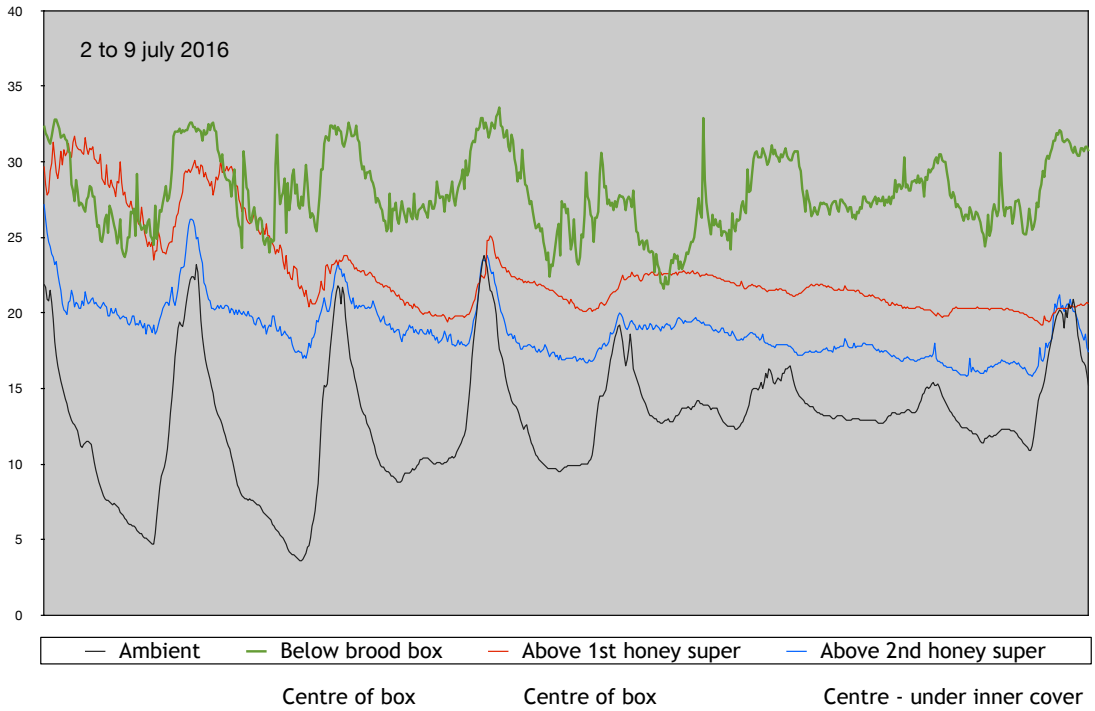
Summer - top vents (brood plus 3 super hive with insulated plywood inner cover + vents)

Base board cavity

Winter - no top vents **(brood plus 2 super hive with insulated plywood inner cover)**



Winter - top vents **(brood plus 2 super hive with insulated plywood inner cover + vents)**



Winter - top vent **(brood plus 2 super hive with insulated plywood inner cover + vent)**