Winter 23-24 Ventilation Observational Study

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What We Investigated Each Winter

2020-2021

*Understand the effects of **moisture** on overwintering hives and how our **winterizing methods might be improved**.*

Reported Cause	2016	2017	2018	2019
#1	Varroa	Varroa	Varroa	Varroa
#2	Don't Know	Don't Know	Starvation	Weak colony
#3	Starvation	Starvation	Moisture	Cold Temps
#4	Other	Moisture	Don't Know	Queen Issues
#5	Weak colony	Cold Temps	Cold Temps	Moisture

2021-2022

*How does the **type of wrap effect the inside temperature** of the colony and bee movement?*

We did NOT investigate or try to answer :

Which wrap is the best for winter survival ?

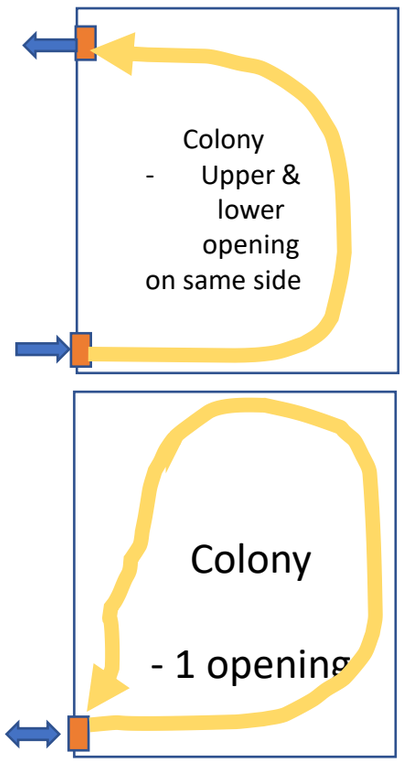
2022-2023

How does colony temp and humidity differ between colonies with:

a single vent at the lower entrance

and

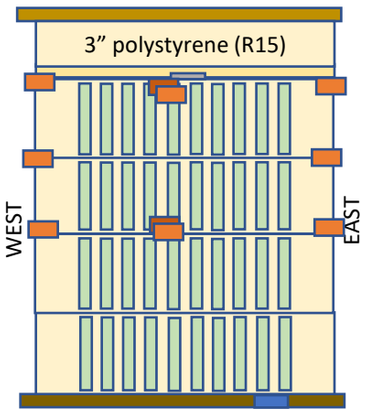
a top and bottom vent?



2023-2024

*Continue to **refine our understanding of winter colony thermodynamics –***

2 different monitoring configurations



3 colonies in 1 apiary instrumented with 10 sensors

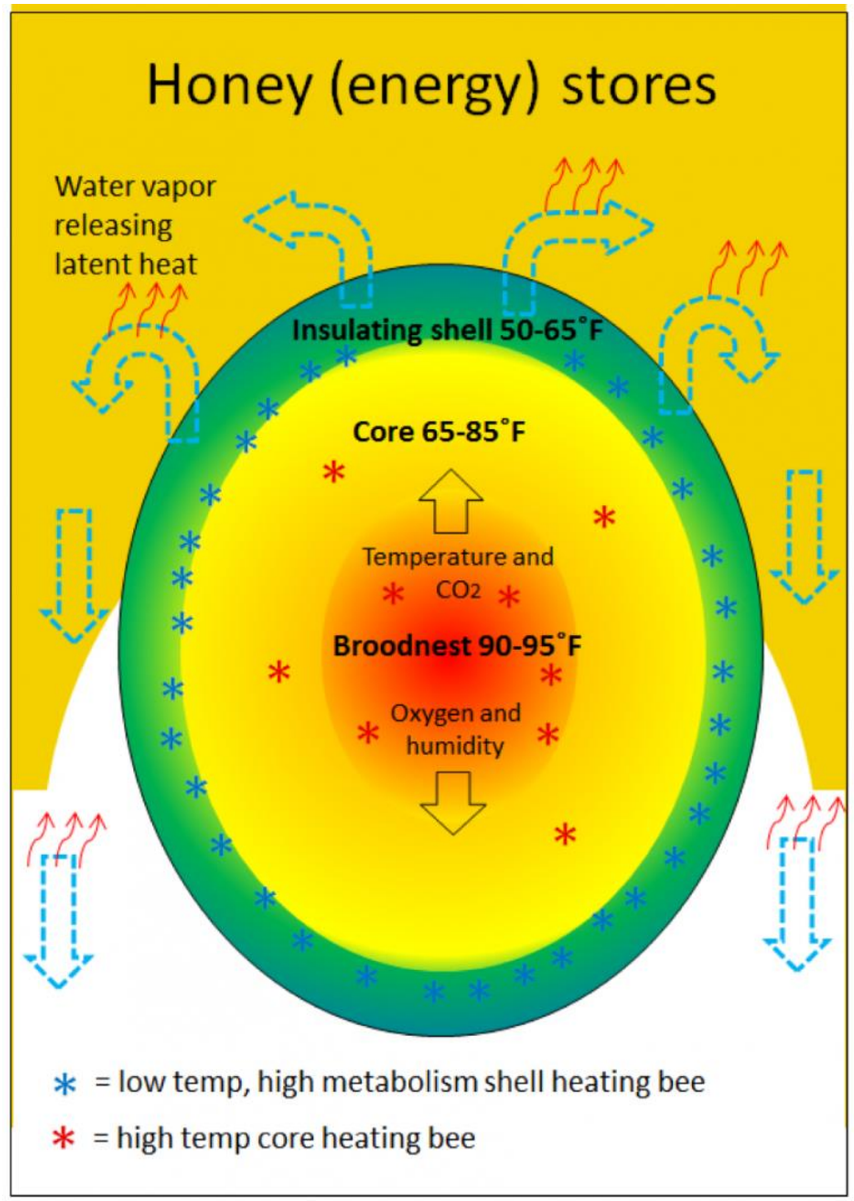
18 colonies in 3 apiaries instrumented with 1-2 sensors

A Little Background

Honeybee Challenges in Cold Climates

- A bee goes into a **"chill coma" below ~43F** and cannot move their flight muscles.
  - They **die within ~48 hours** if they do not warm back up to at least 50F.
- Bees cluster together in order to survive cold weather and avoid lengthy chill coma.
  - The cluster is in layers – outer layer (aka the mantle) being the coldest, core being the warmer.
  - Bees use their flight muscles to keep the outer layer above 45-50F. The core temperature depends on whether they are raising brood.
  - **Oxidative stress from heating the colony may shorten a bee's lifespan.**
- Research shows that bees **use the least energy when winter ambient temperature is ~ 40F**
- **Our Goal of winterizing hive:**
  - Make it a little easier for bees to maintain their cluster temperature
  - Ensure the moisture generated by the bees doesn't adversely affect the colony
  - **Ensure there's enough moisture available for brood rearing & to breakdown winter feed.**

NEW!



Source: Randy Oliver

Sources:
- http://www.millershomestead.com/NCBroodHeatingCooling.pdf;
- Bill Hesbach Middlesex County Beekeepers Association You Tube
- http://scientificbeekeeping.com/understanding-colony-buildup-and-decline-part-13a/ Randy Oliver

Why Do Bees Need Moisture in the Winter?

- Bees need to keep the brood nest between 50-75% RH for eggs to hatch & larval to develop normally.
  - Eggs need Relative Humidity > 55% to hatch!
    - Highest survival is 90-95%
    - At 50% RH – many eggs shriveled and only 2.9% of the ones that didn't produced normal Larval
- Nurse bees require moisture to produce Royal Jelly

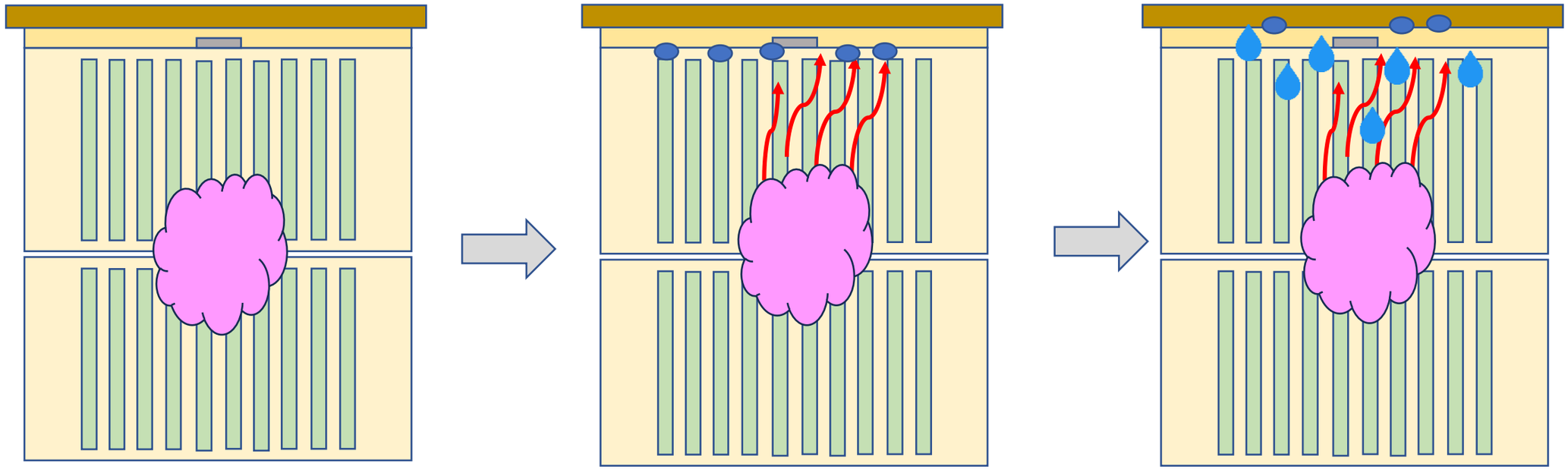
- Sugar (aka candy boards, sugar bricks) needs to be dissolved with water before bees can consume it.
- Bees will fly to collect water even at low winter temps –
  - They use their flight muscles to keep their thorax warm during the collection before going back to the hive

Sources:

- Doull 1976, "**THE EFFECTS OF DIFFERENT HUMIDITIES ON THE HATCHING OF THE EGGS OF HONEYBEES"**
- https://www.beeculture.com/a-closer-look-17/
- **https://scientificbeekeeping.com/observations-on-pollen-subs-part-4-nectar-water-and-humidity/**
- **https://www.researchgate.net/publication/323112409_Cold_flying_foragers_Honey_bees_in_Scotland_seek_water_in_winter**

Thermodynamics in Winter Colonies

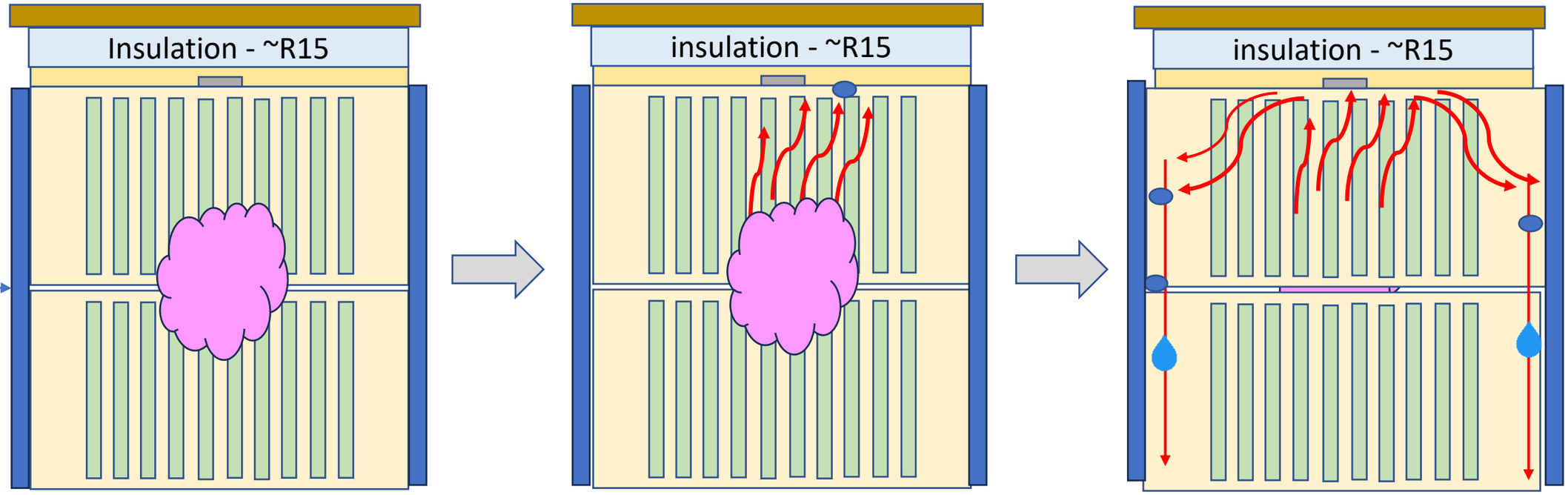
No Insulation



Cluster is generating heat keeping the outside layer at ~50F.

When the warm air hits to cold inner cover, moisture condensing.

As moisture builds up, it can rain down on the cluster



Cluster is generating heat keeping the outside layer at ~50F.

Insulation help keep the inner cover warmer so some condensation may occur but much less

The air flows from the inner cover to the sides which are cold & moisture may condense, but it will run down the side & not on the bees.

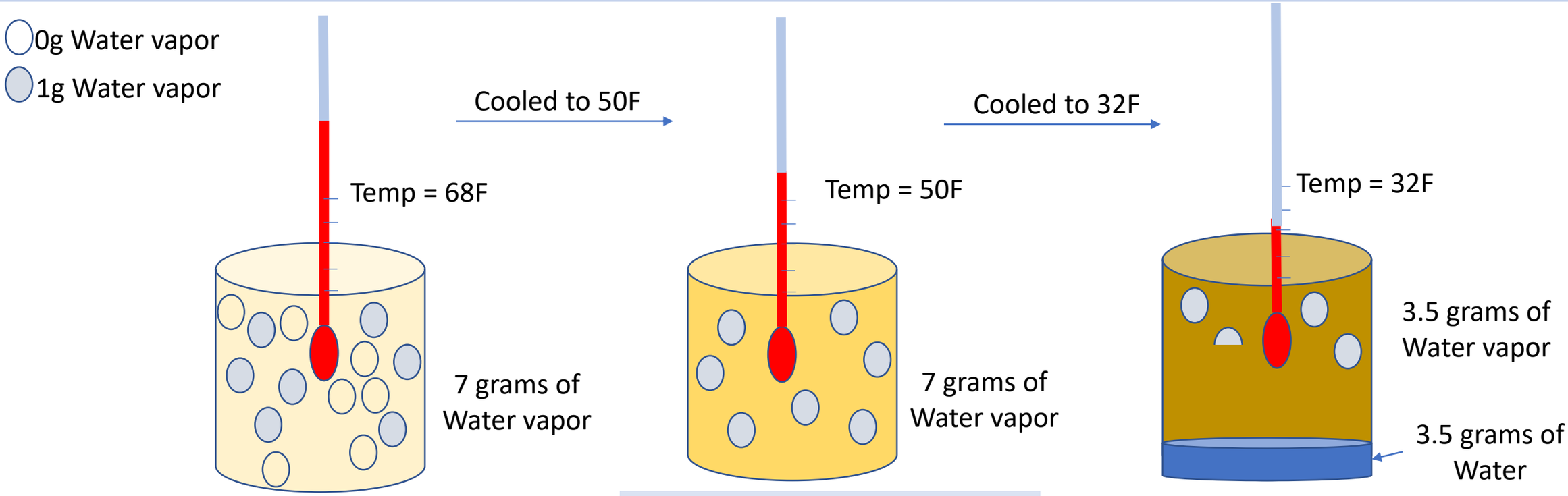
What We Can Measure

Temperature

Relative Humidity(RH)

Relative Humidity (RH) is a ratio:

$$\frac{\text{amount of water vapor in the air}}{\text{max amount of water vapor air can hold at that temp.}}$$

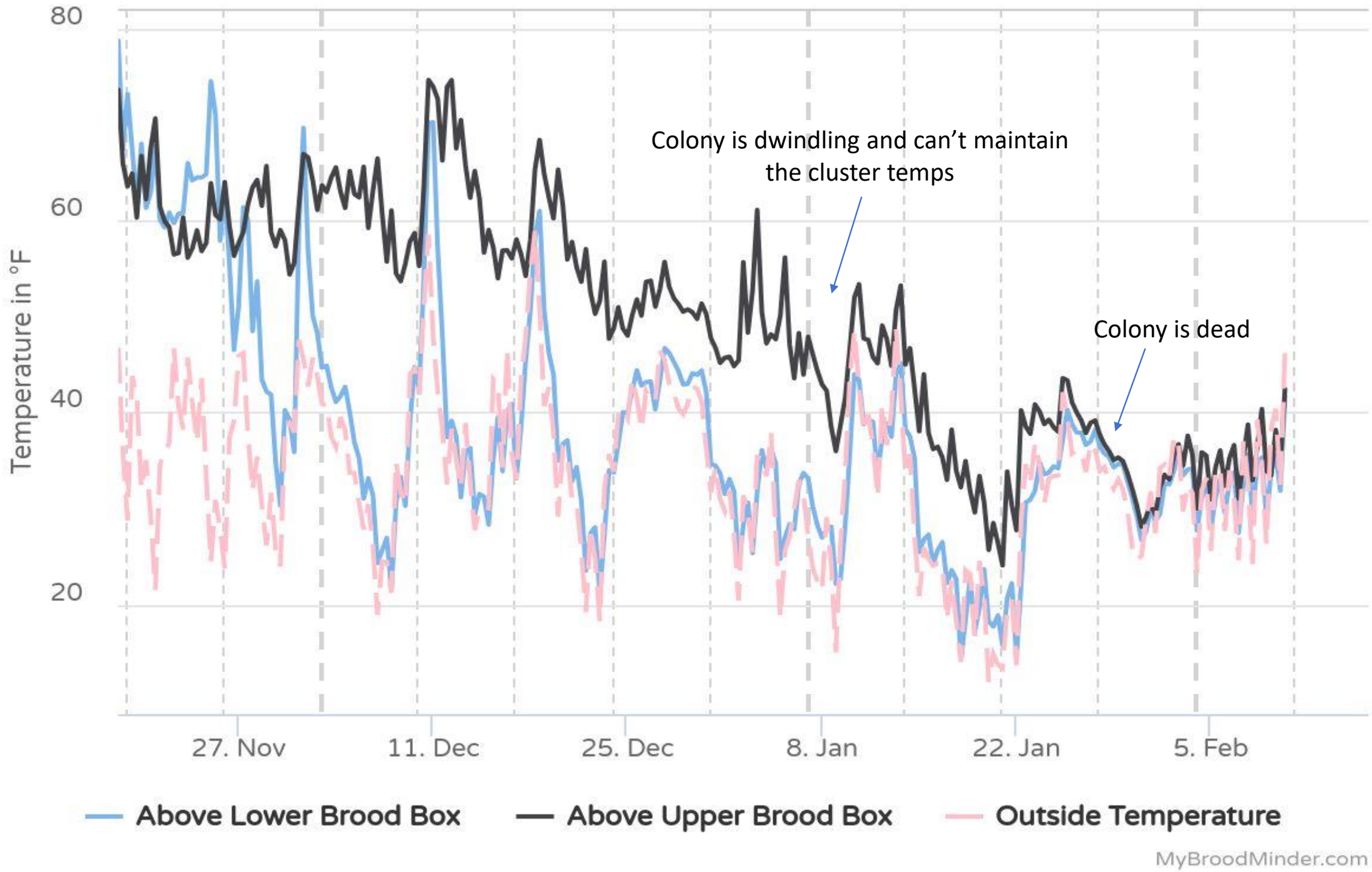


@68F - Air can hold 14g of water vapor
RH: 7/14=50%
VPD = 1.17 g/m3

@50F - Air can hold 7g of water vapor
RH: 7/7 = 100%
VPD = 0 g/m3

@32F - Air can hold 3.5g of water vapor; the rest precipitates out
RH: 3.5/3.5=100%
VPD = 0 g/m3

Temps in a Dwindling Colony



What We Learned This Winter

Bees will break cluster to get moisture to breakdown feed.

Quilt boxes and other moisture absorbing solutions may hinder brood development.

Bees will control the temp & RH at desired levels – by blocking off ventilation, having heating events and creating entrances.

Gaps Matter! Moisture may collect where you don't want it.

Touching the colony can make the bees break cluster.

Need to test sensors to make sure the relative humidity reading is accurate.

Touching a Colony in Winter Can Cause Bees to Break Cluster

Apiary Location:
Gilmanton, NH

10 sensor - Colony setup

Inner cover - entrance : ½" x 3/8" with wind block (see below)

Two of the ten Broodminder sensors

Empty super with 3" of polystyrene/foam insulation (R15)

1 ½" shim with weather Stripping

4 mediums

Lower Entrance
½ oval (1/2"x3/8")
On EAST side of colony

Cinder blocks wrapped with Reflectix

Screened Bottom board closed with ½" Polystyrene

Reflectix "shingled" over cozy

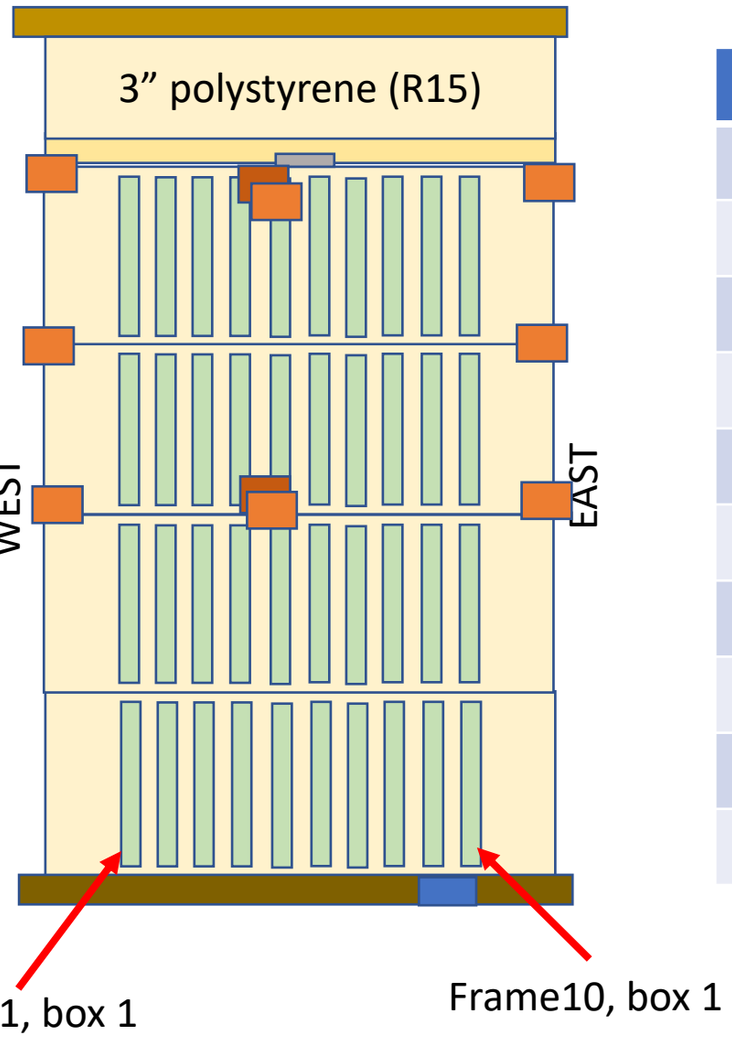
Hollister Bungie

Bee Cozy over a colony quilt R 11.7

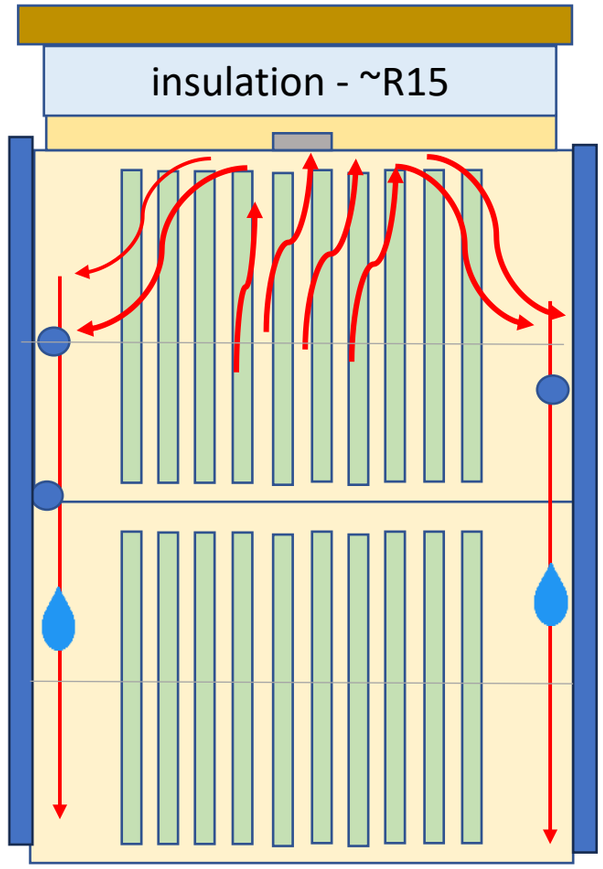
Wind block on inner cover opening

Broodminder Sensor Setup

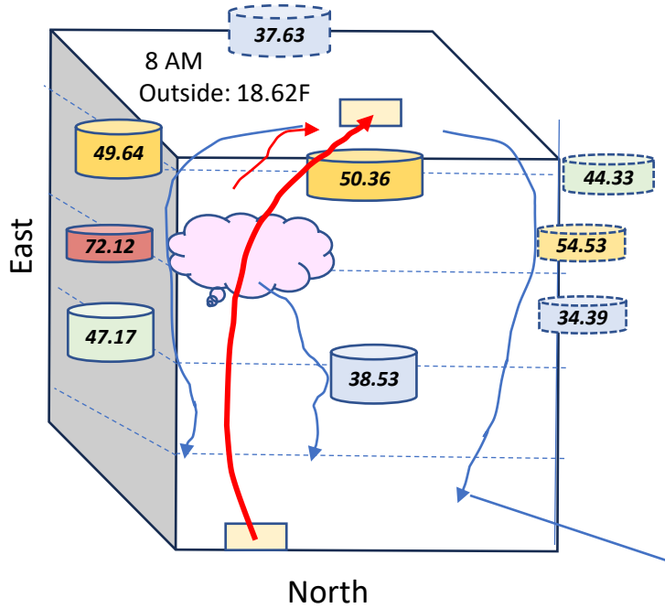
- **10 Broodminder Sensors installed in the colony**
  - North & South Sensors on frame 5 – 2” from woodenware
  - East Sensor – center of east side 2” from woodenware
  - West Sensor – center of west side 2” from woodenware
- Apiary Temperature from Broodminder sub hub installed on apiary fence pole (doesn’t measure RH)

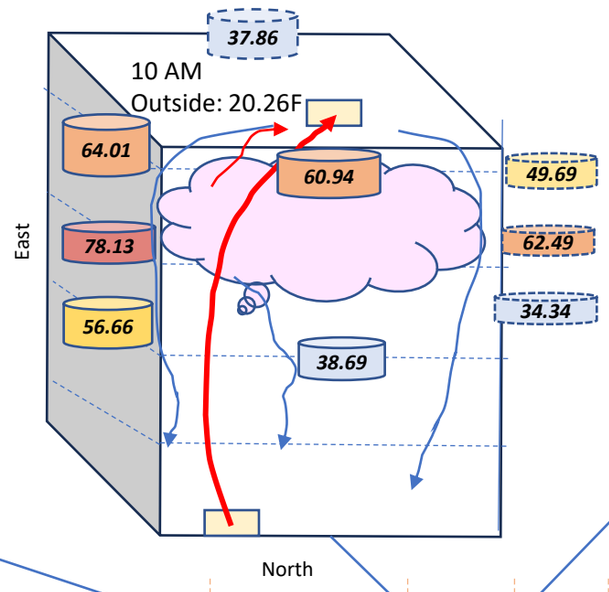


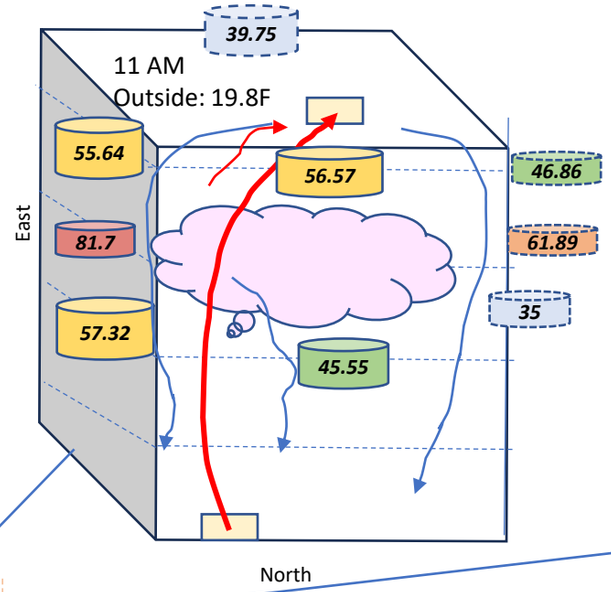
Sensor	Type	Location
#1	Temp/RH	Box 2-North
#2	Temp/RH	Box 2-South
#3	Temp/RH	Box 2-East
#4	Temp/RH	Box 2-West
#5	Temp/RH	Box 3-East
#6	Temp only	Box 3-West
#7	Temp/RH	Box 4-North
#8	Temp/RH	Box 4-South
#9	Temp/RH	Box 4-East
#10	Temp/RH	Box 4-West

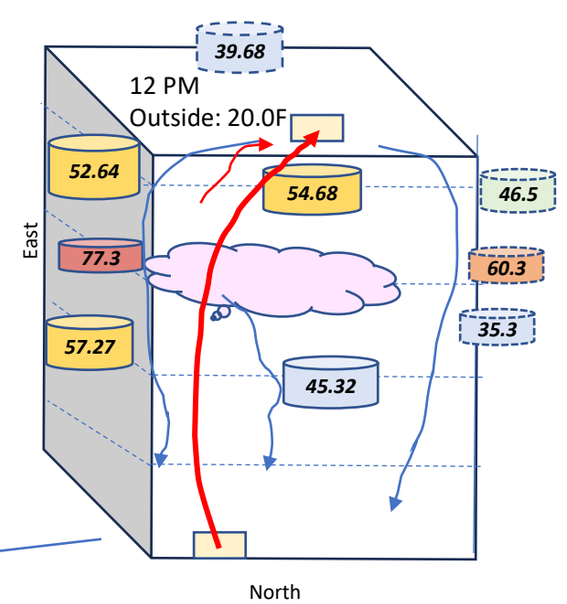


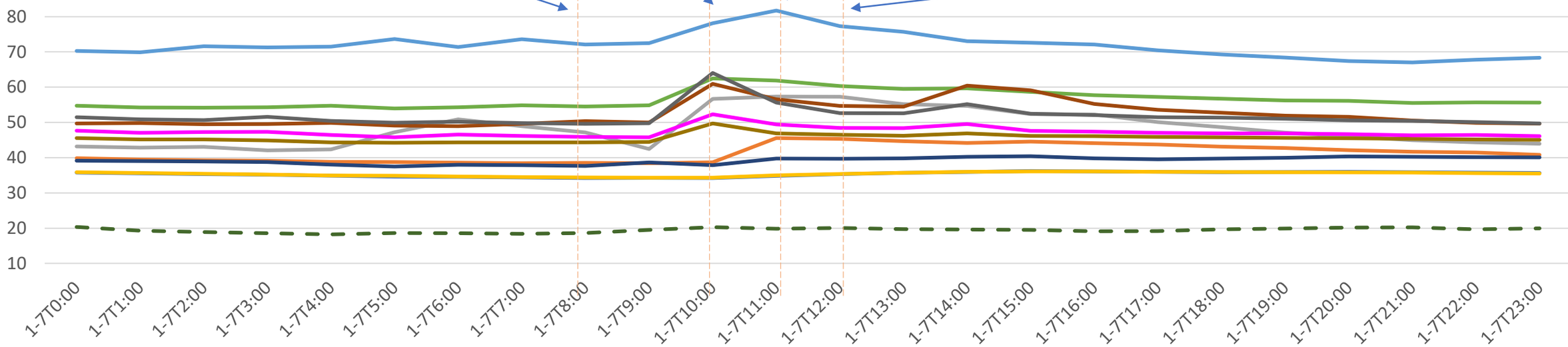
Brushing snow off colony at 9ish am











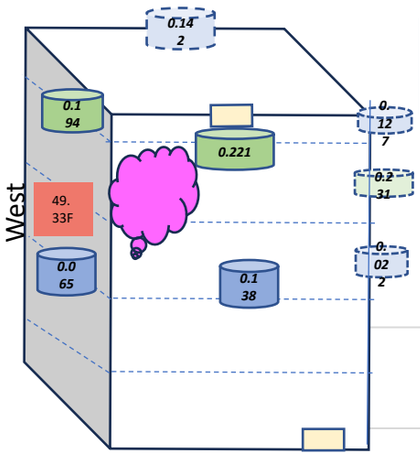
	box2-north-Temp	box2-east-Temp	box2-west-Temp	box3-east-Temp	box3-west-Temp	box4-south-Temp	box4-north-Temp	box4-east-Temp	box4-west-Temp	outdoor
1-7T8:00	38.53	47.17	34.39	72.12	54.53	37.63	50.36	49.6	44.33	18.62
1-7T9:00	38.4	42.45	34.32	72.46	54.82	38.64	49.96	49.73	44.42	19.48
1-7T10:00	38.69	56.66	34.34	78.13	62.49	37.86	60.94	64.01	49.69	20.26
1-7T11:00	45.55	57.32	35	81.71	61.89	39.75	56.57	55.64	46.86	19.86
1-7T12:00	45.32	57.27	35.38	77.3	60.31	39.68	54.68	52.64	46.5	20.04
1-7T13:00	44.67	55.18	35.69	75.66	59.5	39.79	54.46	52.6	46.23	19.72

Practical Application: Any disturbance of the colony – even very small – will cause the bees to break cluster to investigate

Bees will Block Airflow and Break Cluster to Increase Moisture for Feeding

updated

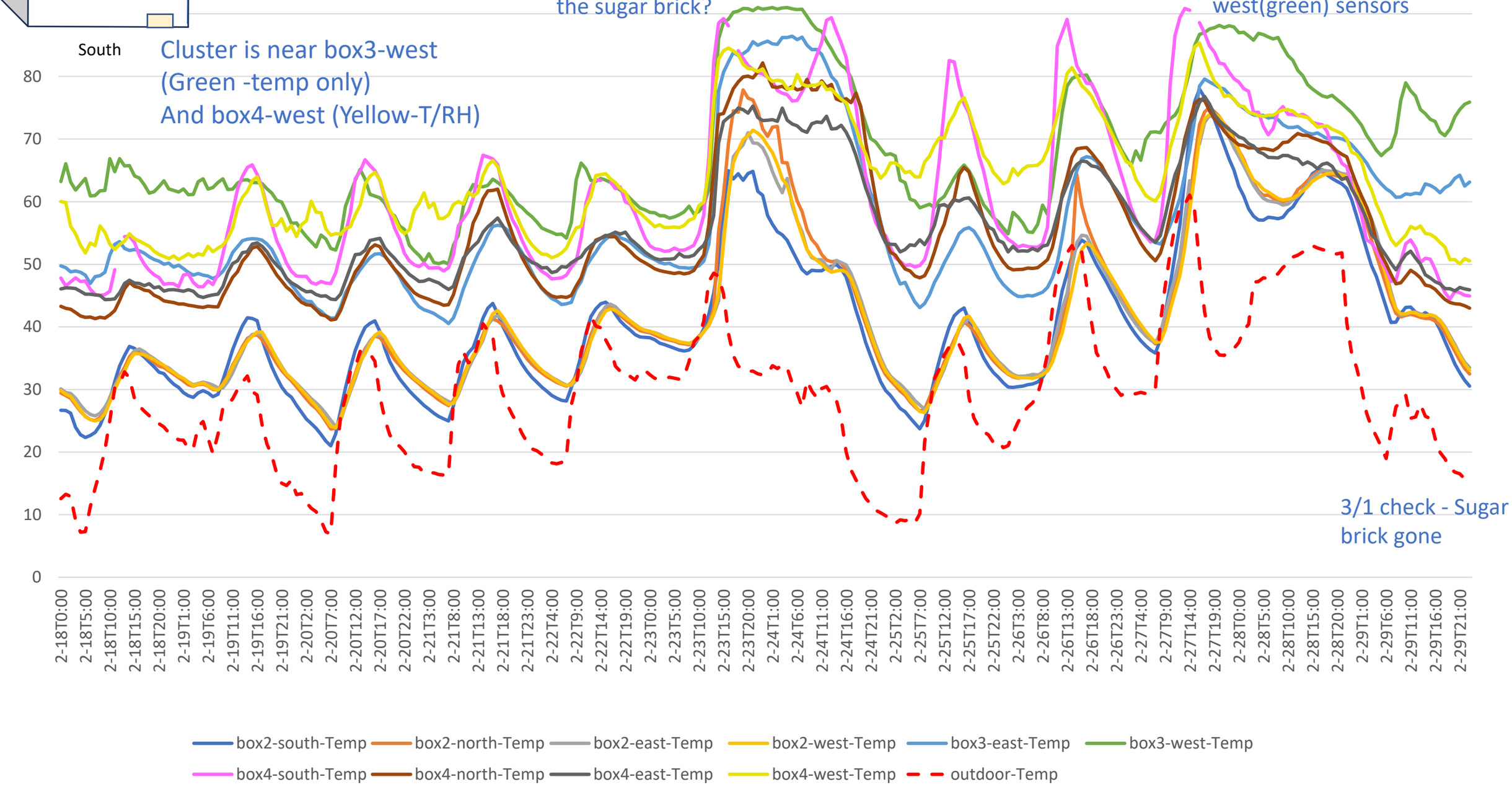
Hourly Data – Sask2- 2/18-29



Added 1 lb. sugar brick (2/23 @1pm) note that bees spread out between box3-east & west sensors for about 24 hours – is that how long it took to consume the sugar brick?

When temps drop cluster moved back down to box3 and spread between east (blue) & west(green) sensors

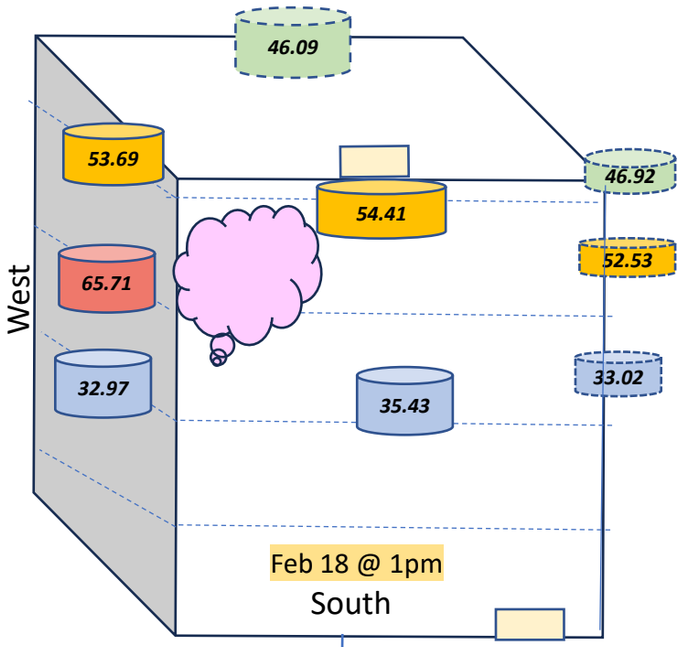
Cluster is near box3-west
(Green -temp only)
And box4-west (Yellow-T/RH)

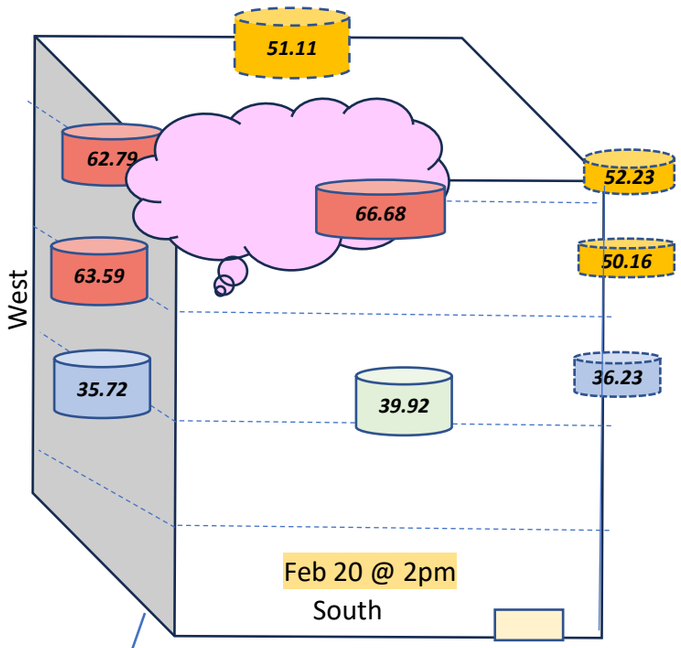


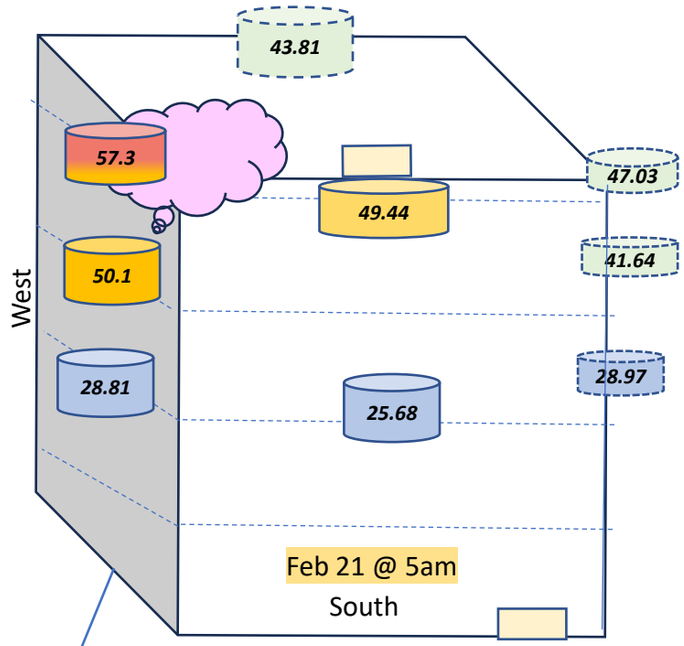
3/1 check - Sugar brick gone

When sun warms the colony, bees move toward the box4-south sensor (pink) which is ~2” below the upper entrance - are they trying to move moisture?

Temperature – Sask2- 2/18-22



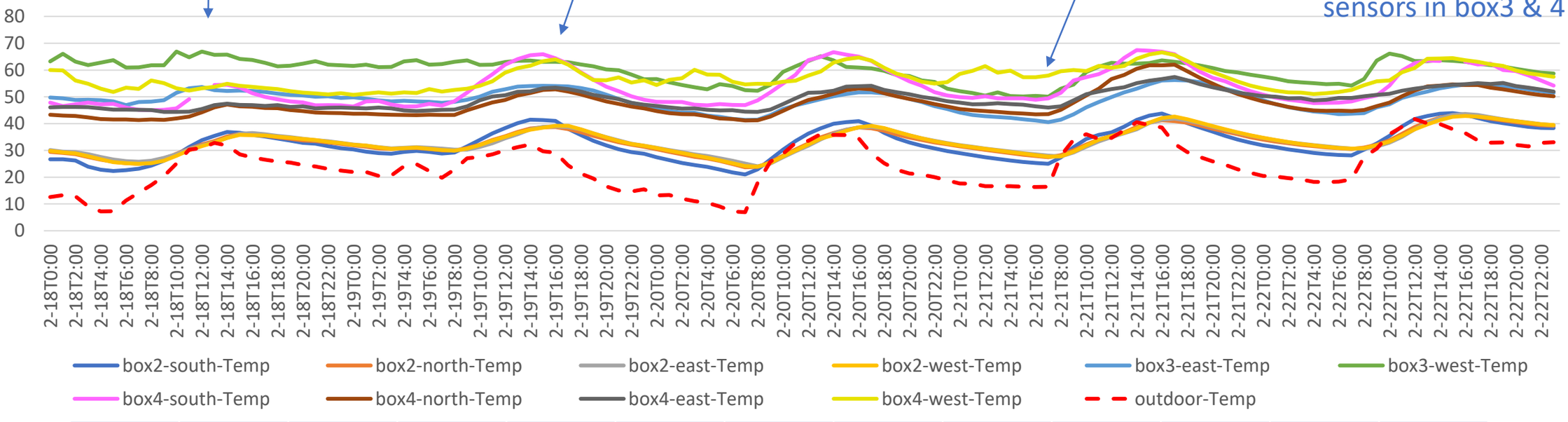




Bees cluster near box3-west sensor

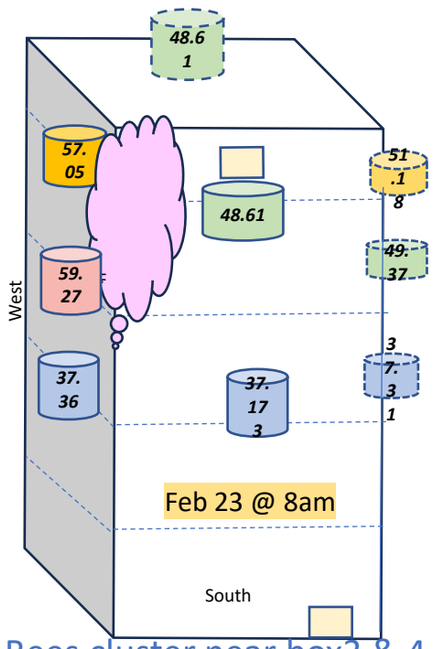
Sun warms colony – bees move toward box4-south – are they trying to move moisture?

When cools down at night the bees cluster toward the west sensors in box3 & 4

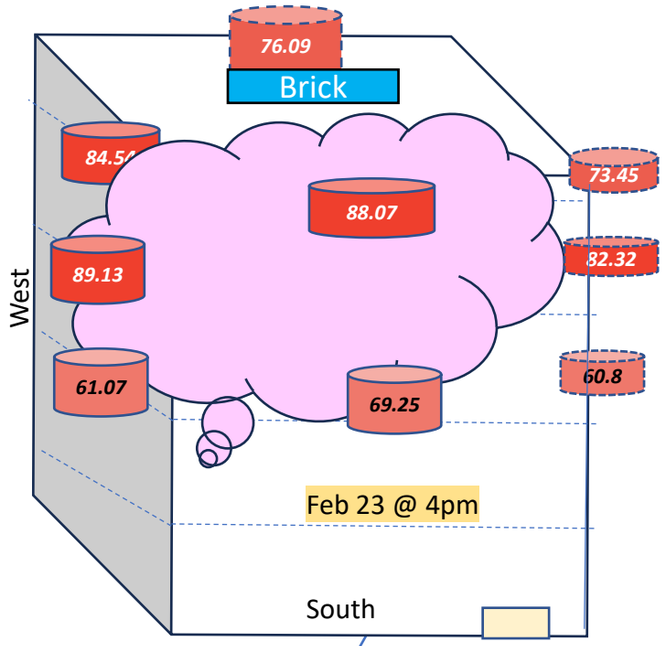


timestamp	box2-south-Temp	box2-north-Temp	box2-east-Temp	box2-west-Temp	box3-east-Temp	box3-west-Temp	box4-south-Temp	box4-north-Temp	box4-east-Temp	box4-west-Temp	above-inner-cover-Temp	outdoor-Temp
2-18T13:00	35.43	33.51	33.02	32.97	52.53	65.71	54.41	46.09	46.92	53.69		32.81
2-20T14:00	39.92	36.51	36.23	35.72	50.16	63.59	66.68	51.11	52.23	62.79		35.81
2-21T5:00	25.68	28.36	28.97	28.81	41.64	50.1	49.44	43.8	47.03	57.3		16.43

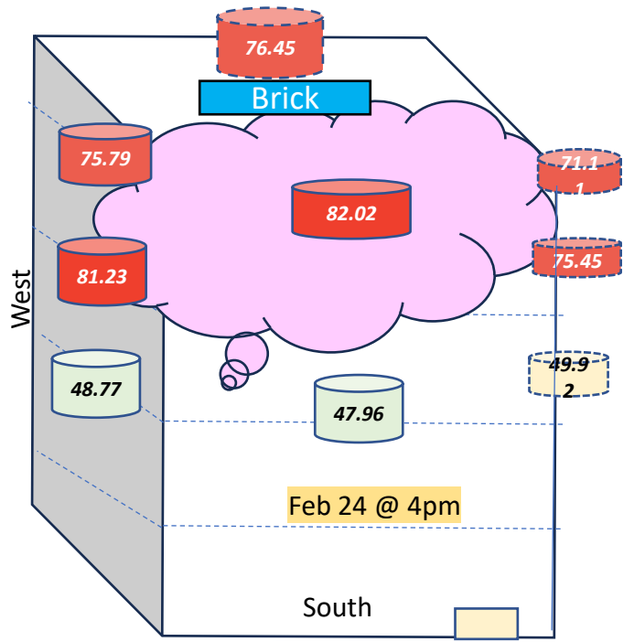
Add Sugar Brick – Sask2- 2/23-25



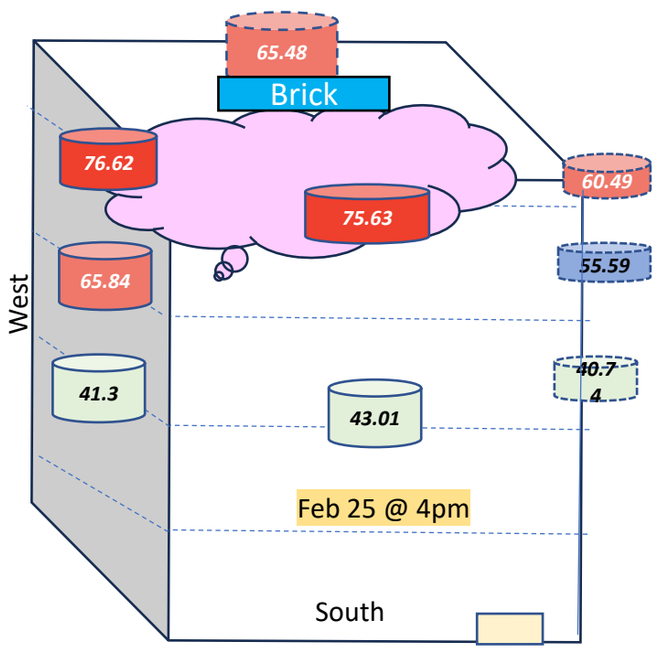
Bees cluster near box3 & 4-west sensor



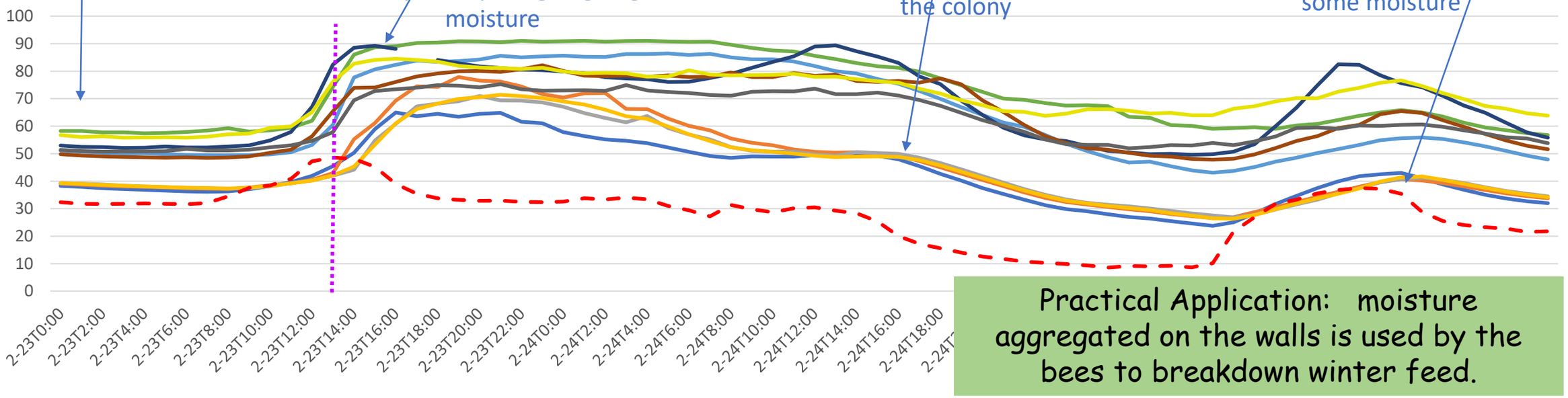
Add sugar brick at 1pm – some bees went to the– note how box2 sensors warm up – they are going to get moisture



cluster contracted a little, but still gathering moisture from cold parts of the colony



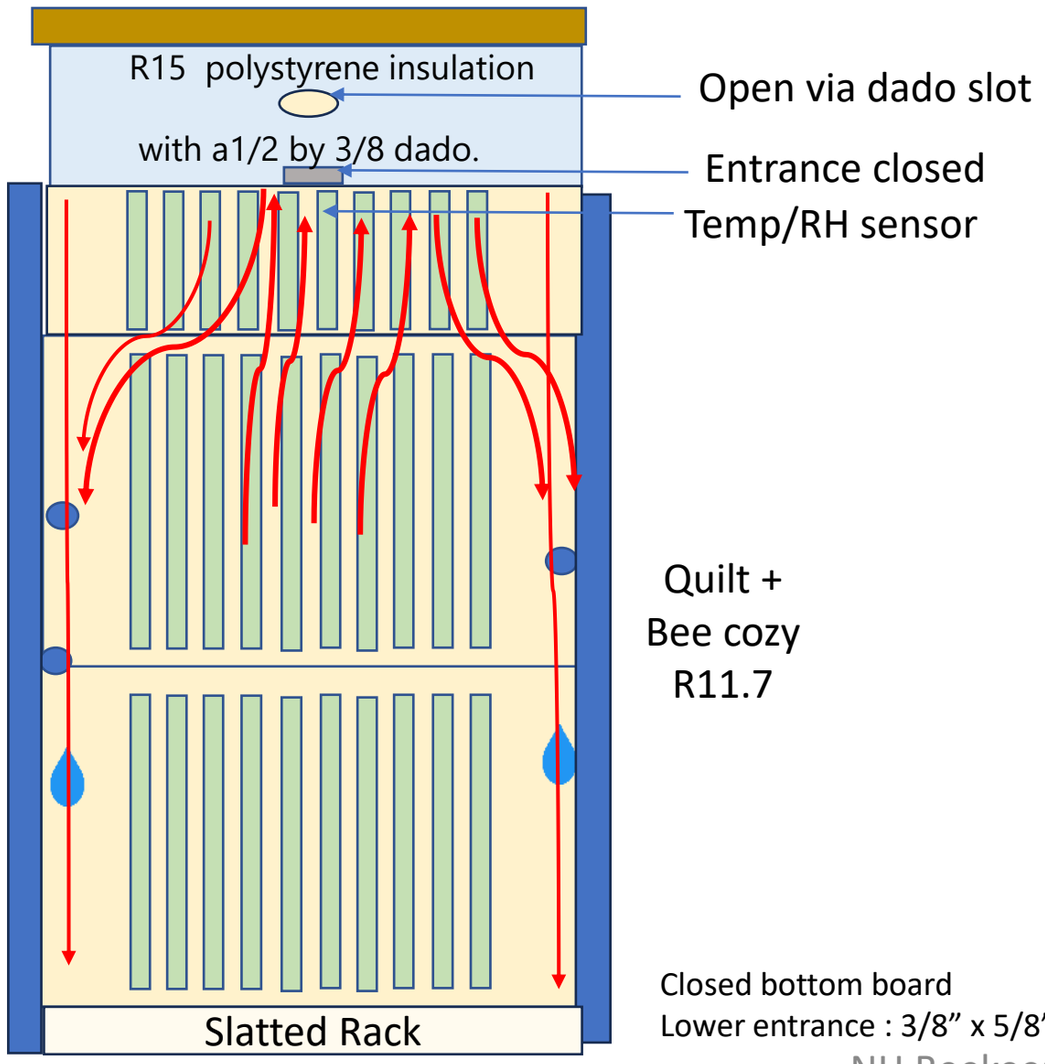
As brick is eaten, cluster continues to contract, but still gathering some moisture



Practical Application: moisture aggregated on the walls is used by the bees to breakdown winter feed.

timestamp	box2-south-Temp	box2-north-Temp	box2-east-Temp	box2-west-Temp	box3-east-Temp	box3-west-Temp	box4-south-Temp	box4-north-Temp	box4-east-Temp	box4-west-Temp	outdoor-Temp
2-23T8:00	36.3	37.14	37.31	37.36	49.37	59.27	52.62	48.61	51.18	57.05	34.48
2-23T16:00	64.97	69.25	60.8	61.07	82.32	89.13	88.07	76.09	73.45	84.54	39
2-24T16:00	47.96	49.11	49.92	48.77	75.45	81.23	83.03	76.45	71.11	75.79	20.04
2-25T16:00	43.01	40.74	40.74	41.39	55.59	65.84	75.63	65.48	60.49	76.62	35.43

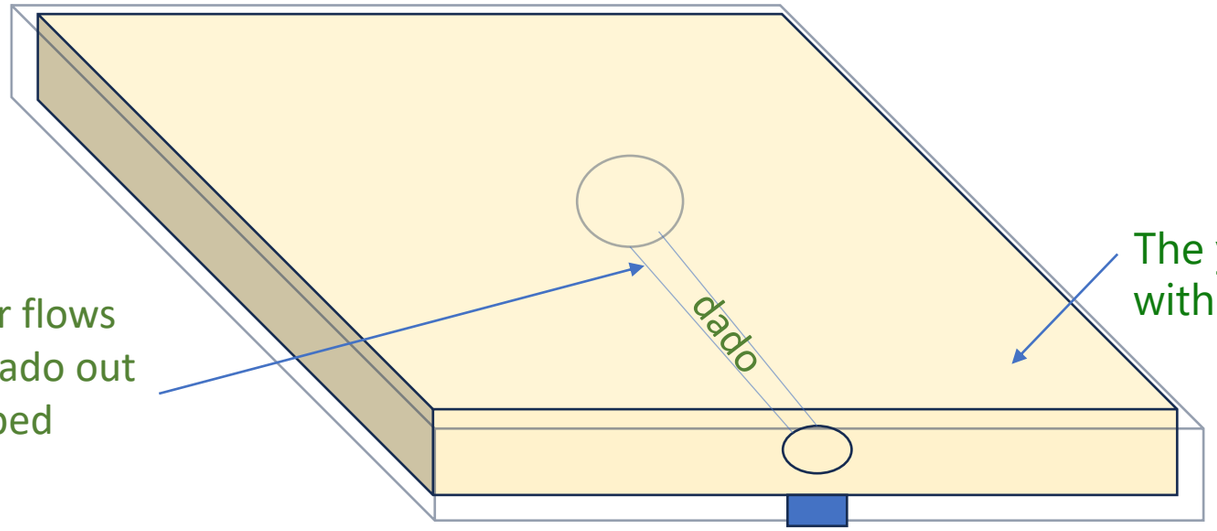
Bees Manage the Airflow in the Colony



Mann Lake Winter Inner Cover

1″ insulation
R-5.0

Construction: Plywood with a hole in the center is ~ ¼-3/8” above the bottom of a 2” high wooden frame to allow for the lower entrance notch

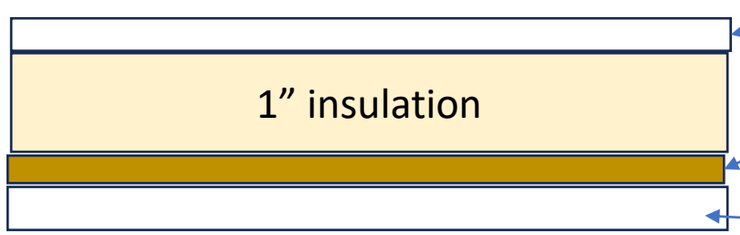


White Cap removed so air flows from inside colony thru dado out the hole with yellow capped removed

The yellow insulation goes inside with the dado down.

1/4 x 3/4 entrance

Side view from inside the cover



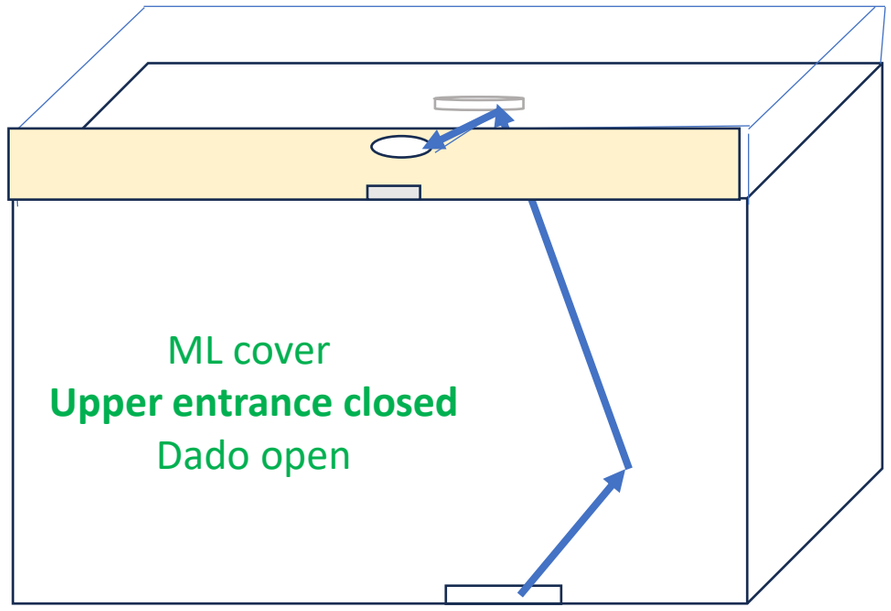
Air space above insulation (1/2”)

Plywood (5/16”)

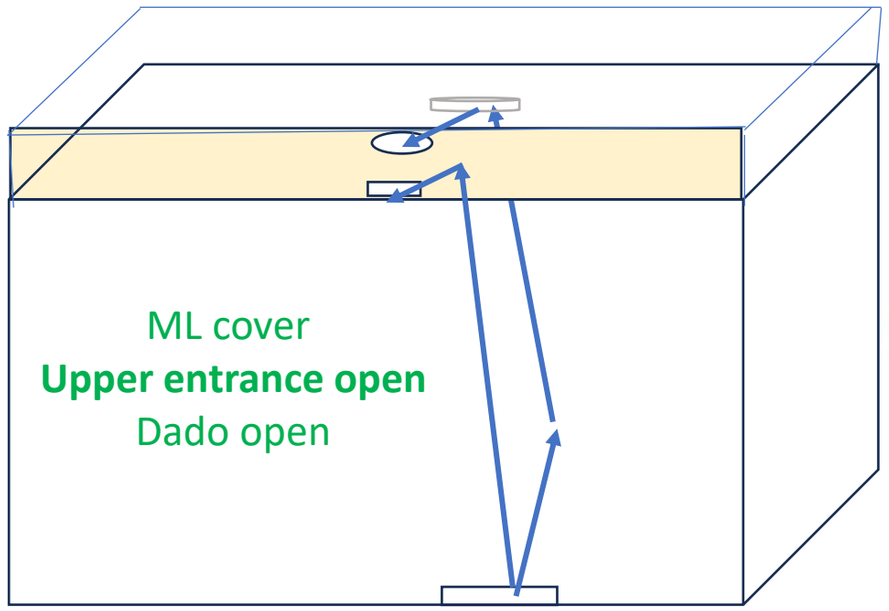
Air space below plywood (giving area for lower entrance) (1/4”)

Airflow & Inner Cover Choices

WITH MANN LAKE WINTER INNER COVER

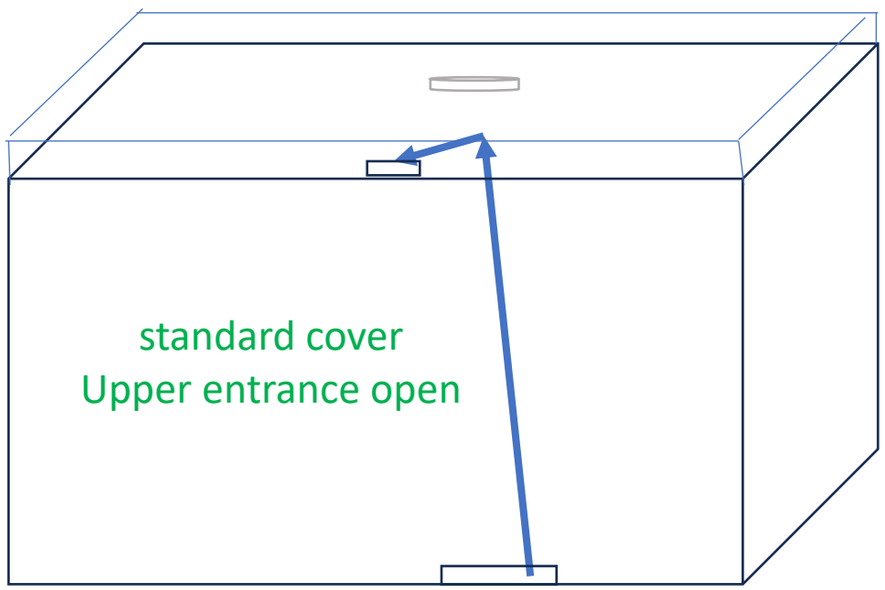


Air flow goes from lower entrance toward middle of the box, out the hole in the middle of the ML cover, through the dado and out the hole



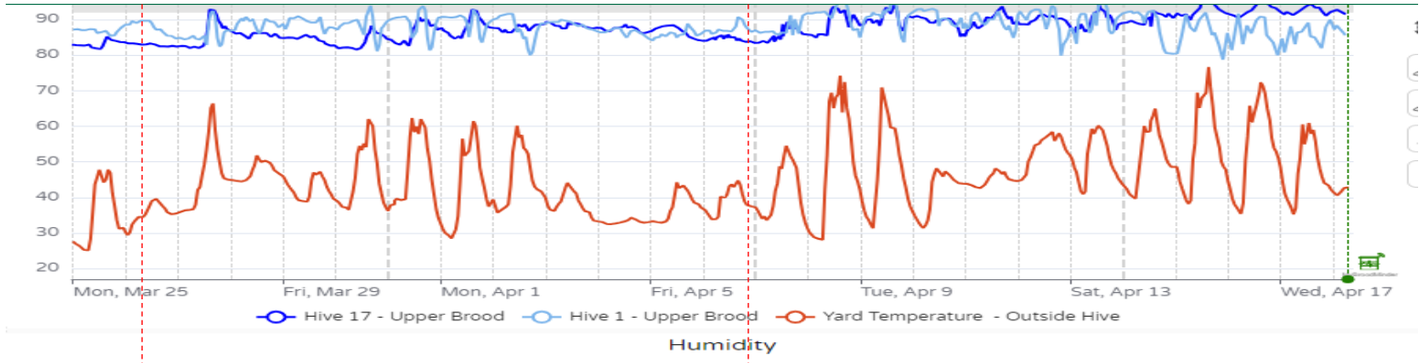
Air flow goes from lower entrance toward middle of the box, out the hole in the middle of the ML cover, through the dado and out the hole AND goes from the lower entrance up the front and out the upper entrances

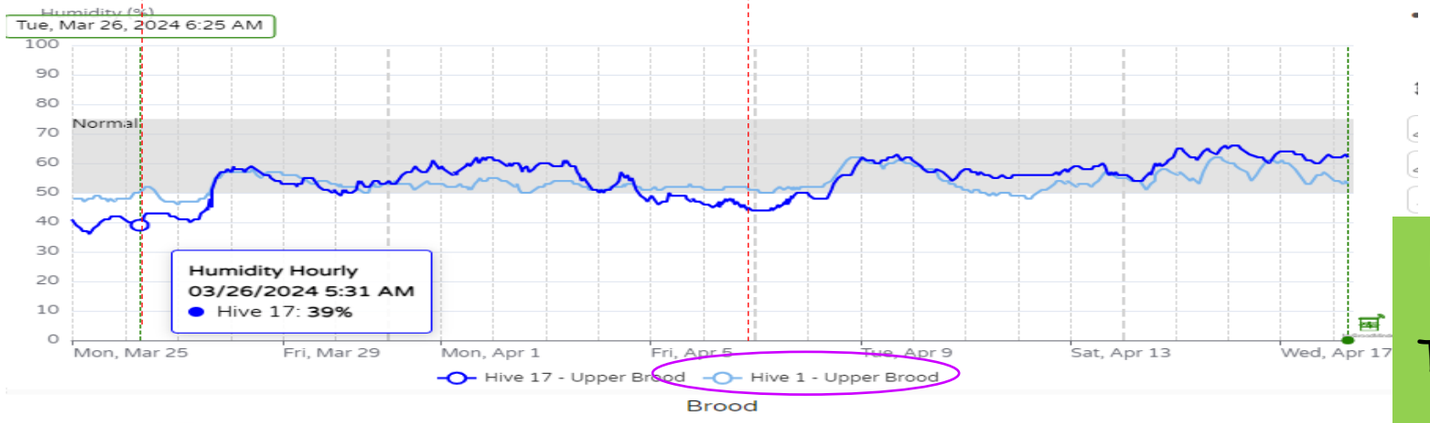
WITH STANDARD INNER COVER

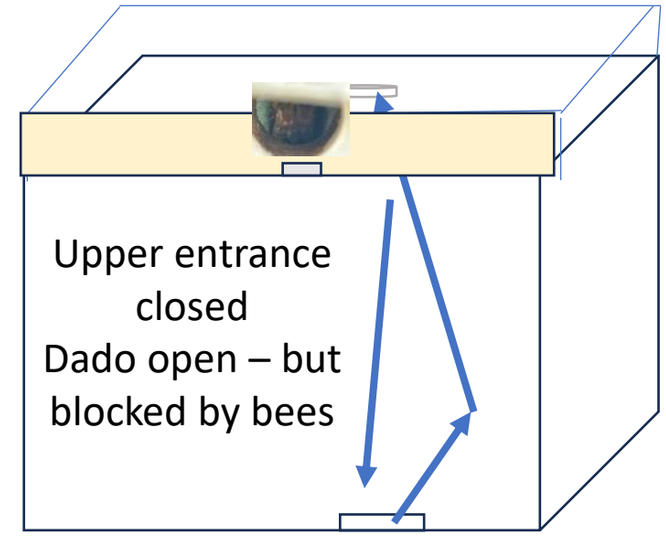


Air flow goes from the lower entrance up the front and out the upper entrances

Bees Controlling Airflow to Maintain RH & Temp







Bees raising brood need to maintain RH between 50-70%

They will block entrances, fan, etc. to control the airflow to maintain the needed environmental conditions

Bees are blocking the airflow out the dado, square notch closed

The bees controlling the airflow through the center of the Mann Lake cover. Upper entrance (square notch) closed

Bees Will Create Their Own Entrances if They Need More Airflow- Winter 2022-23

Full-size Condensing Hive configuration

4 mediums with slatted rack , 1.5” feeding shim, inner cover
B**ottom Board:** closed
Top Insulation: 3" polystyrene
M**oisture System**: None
Wrap: Bee Cozy with Refletix shingle
U**pper Entrance** : No
Lower Entrance : 1.8" x 3/8"

Spray-foam insulation filled the hole in the shim before reflectix was added.

Bees chewed away the insulation that was filling the hole in the shim creating an upper entrance

Bees Will Create Their Own Entrances – Winter 2023-24

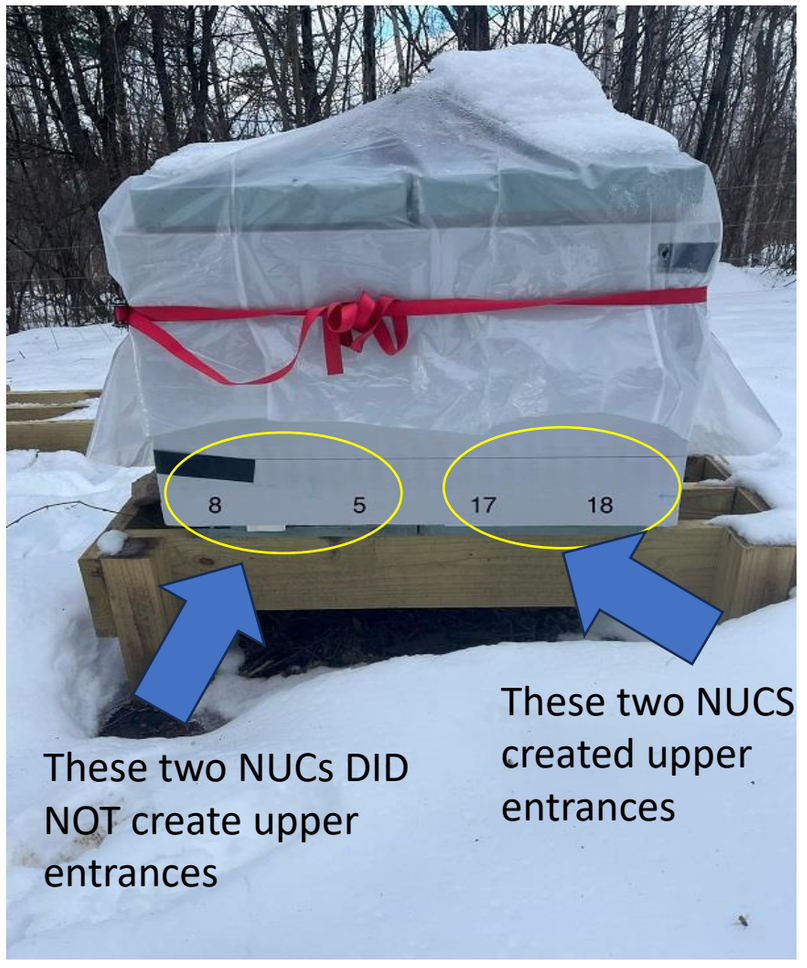
Both colonies created upper entrances

5 full-size colonies:

- 2 created upper entrance (details on left)
- 2 with double deep with slatted rack and 1 with single deep NO slatted rack did NOT create upper entrances

4 NUCs (all the same configuration)

- 2 created upper entrances
- 2 did not create upper entrances



Full-size Condensing Hive configuration

Single deep with slatted rack , 2” feeding shim, no inner cover
Outer Cover: Migratory
B**ottom Board:** closed
Top Insulation: 4" polystyrene
M**oisture System**: None
Wrap: 2" Polystyrene with tarp loosely wrapped around it, sistered next to another colony
U**pper Entrance** : No
Lower Entrance : 1.5" x 3/8"

NUC Condensing Hive configuration

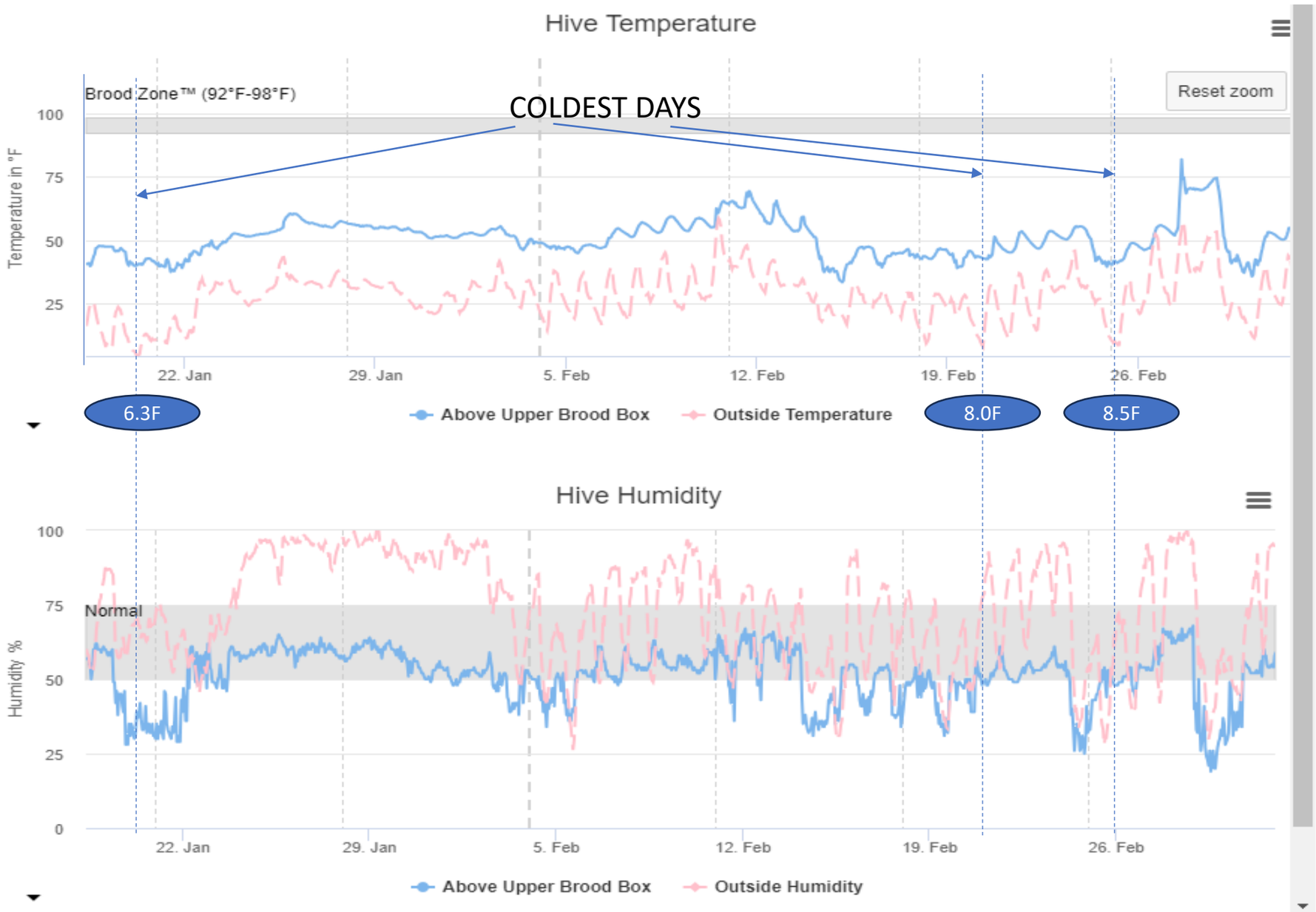
Divided deep, 4 frame NUC,
Deep, Deep, 2" feeding shim, no inner cover, no slatted rack
Outer Cover: Migratory
B**ottom Board:** closed
Top Insulation: 4" polystyrene
M**oisture System**: None
Wrap: 2" Polystyrene with Tarp loosely wrapped around hive sistered with colony #18
U**pper Entrance** : No
Lower Entrance : 2" x 3/8"

Hive 3 created 2 entrances!

Full-size Condensing Hive configuration

Single deep with slatted rack , 2” feeding shim, no inner cover
Outer Cover: Migratory
B**ottom Board:** closed
Top Insulation: 4" polystyrene
M**oisture System**: None
Wrap: 2" Polystyrene with tarp loosely wrapped around it, sistered next to another colony
U**pper Entrance** : No
Lower Entrance : 1.5" x 3/8"

Should NUC 17 Have Created an Upper Entrance?



Bees have little control on the humidity.

Could it be that the airflow was too much?

The development of brood would be hard on the hive.

NUC Condensing Hive configuration

Divided deep, 4 frame NUC,
Deep, Deep, 2" feeding shim, no inner cover, no slatted rack
Outer Cover: Migratory
B**ottom Board:** closed
Top Insulation: 4" polystyrene
M**oisture System**: None
Wrap: 2" Polystyrene with Tarp loosely wrapped around hive sistered with colony #18
U**pper Entrance** : No
Lower Entrance : 2" x 3/8"

Colony Notes

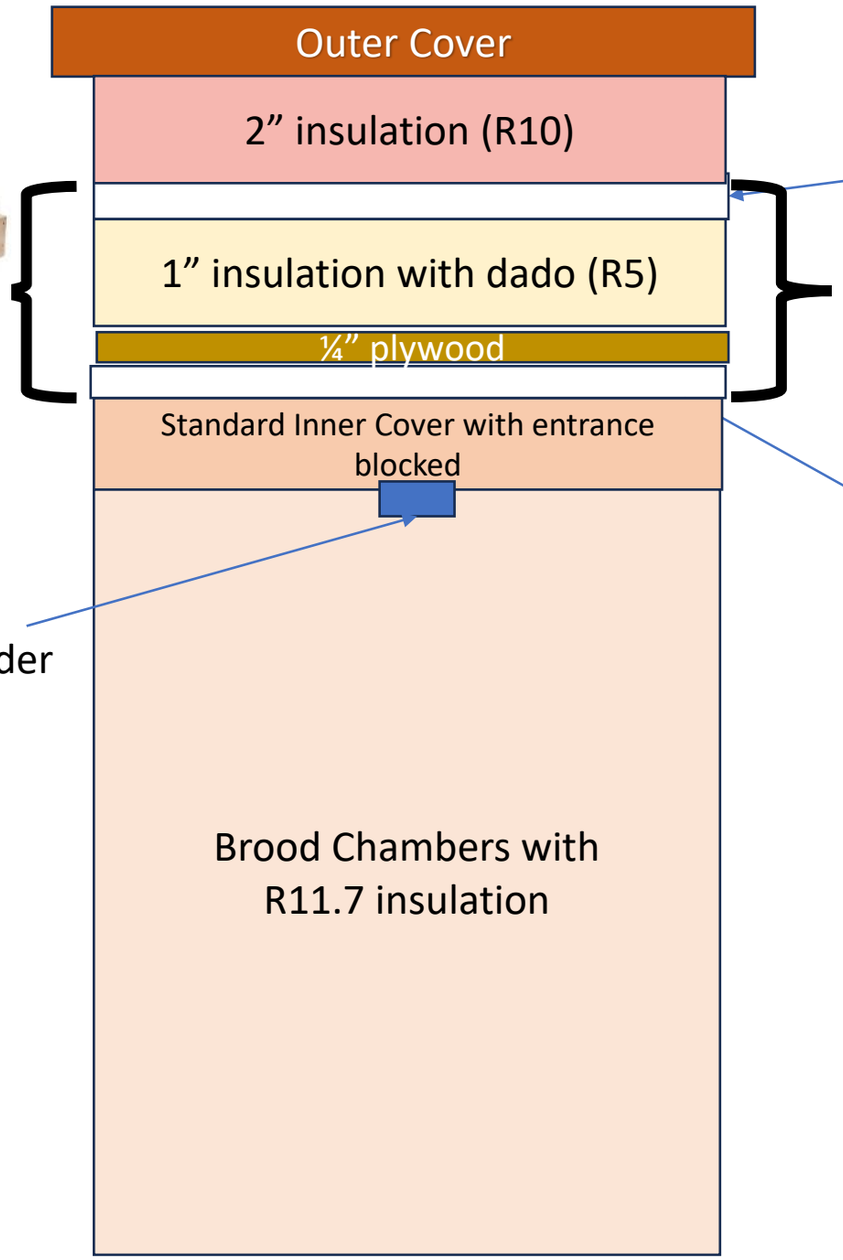
- made entrance on same side as bottom opening
- 4/9 : ¼ frame eggs, no larva or capped brood. 5 frames of bees, one frame honey. No moisture/mold seen.

Mold on Inner Covers

Winter Setup using Mann Lake Cover

Mann Lake Wintering Inner Cover

Side view

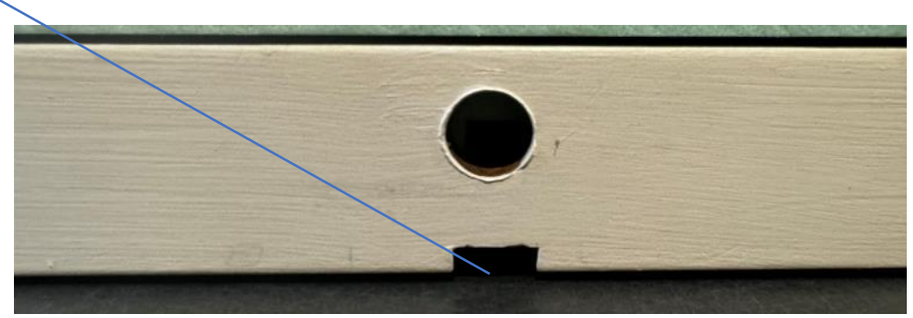


Total Insulation:

Side = R 11.7

Top = R15 with airspace gaps

Air space (1/2”) above insulation because insulation sits ON TOP of Mann Lake Cover NOT inside

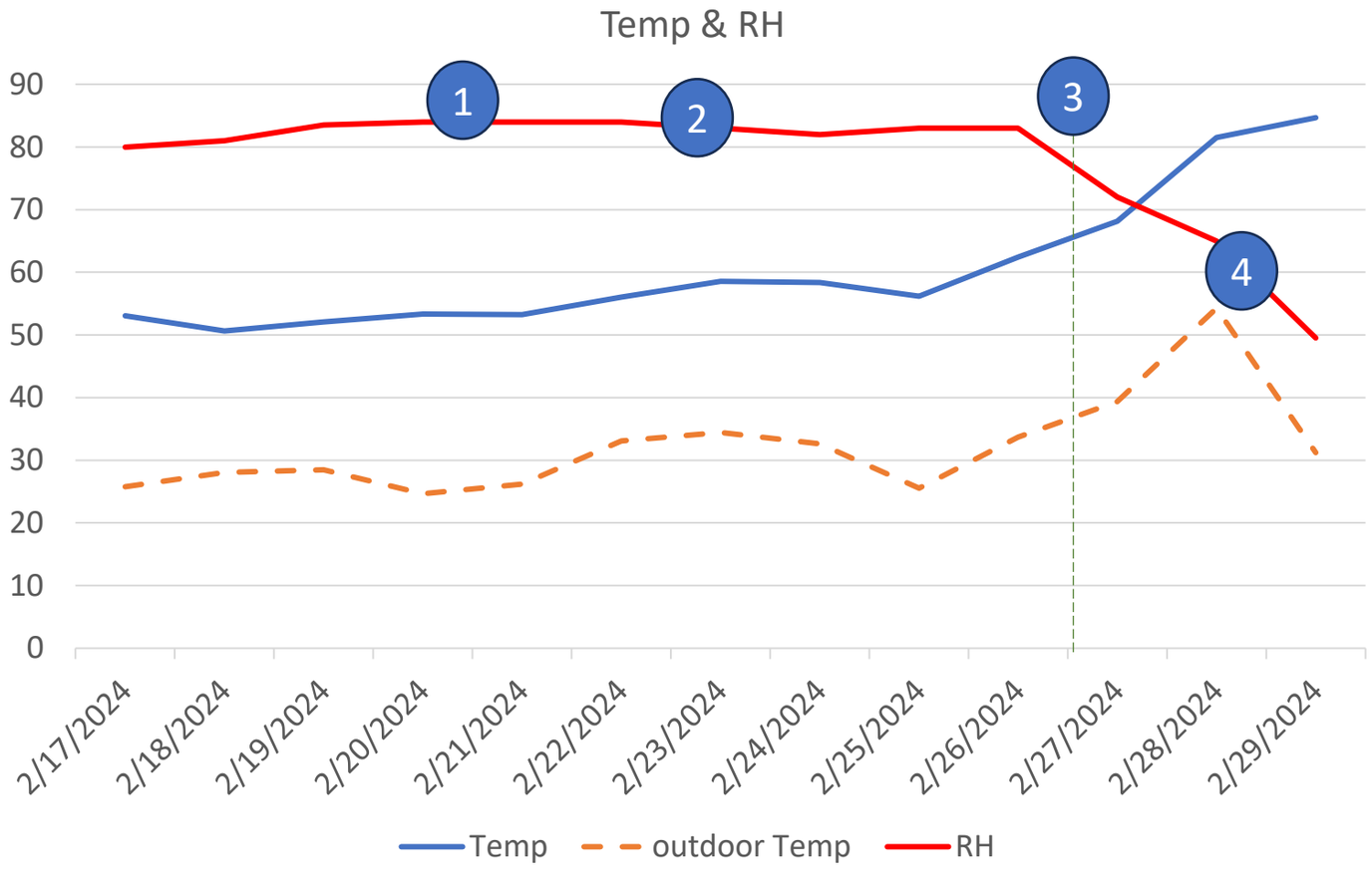


Air space (1/4”) below plywood. This is the space for the lower entrance

Why do we care about the air spaces? Do they matter?

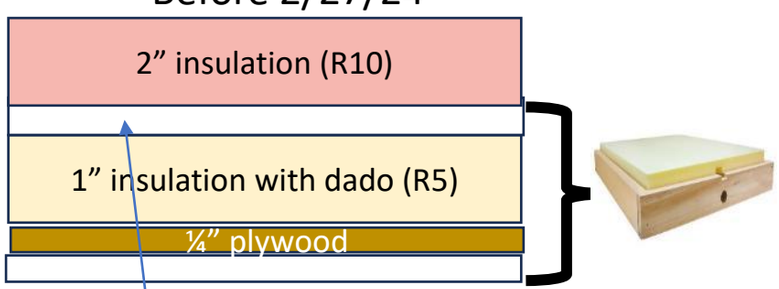
- No insulation in these air spaces means there can be a “cold spot” in the colony
  - Heat/cold will transfer through the wooden frame
- Moisture can condense when warm moist air from the cluster hits the cold spot

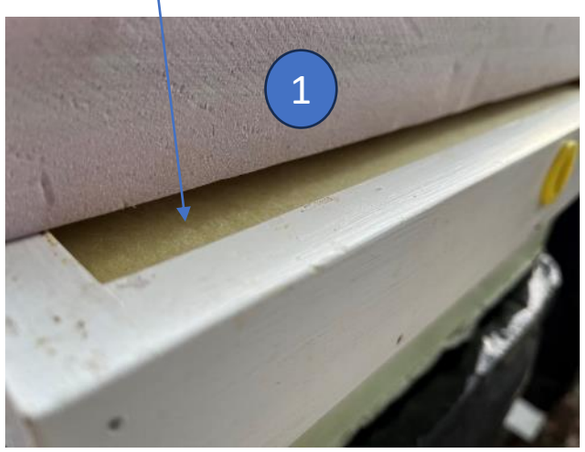
Condensation on Inner Cover

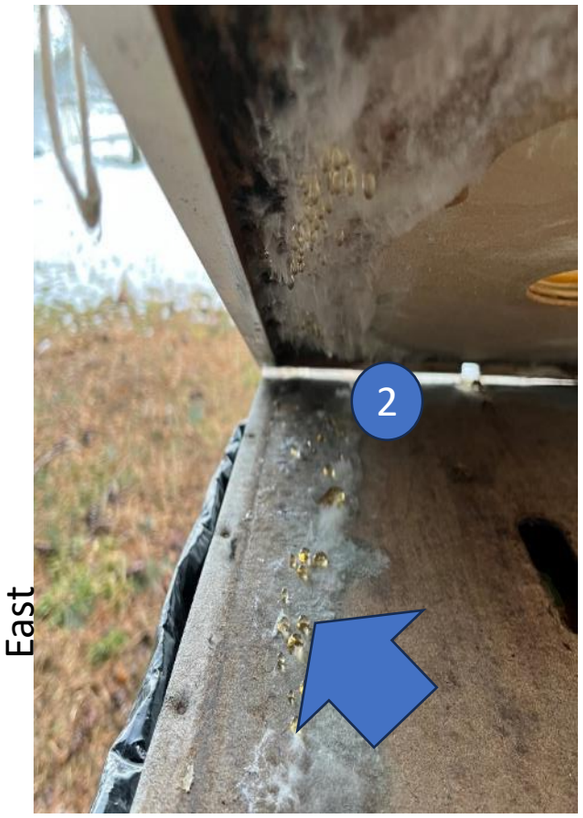


1. Note the high RH (Red) from 2/17→2/26
   - RH> 80%, VPD ~ 0.27
2. Inspection found moisture (see picture) between the inner covers
3. Modified the “pink” 2” insulation by rabbeting the edge so it sat in the inner cover and not on top
4. Removing the airspace between the two insulations improved R-value and RH dropped. (there is still a cold air space between the 2 inner covers)

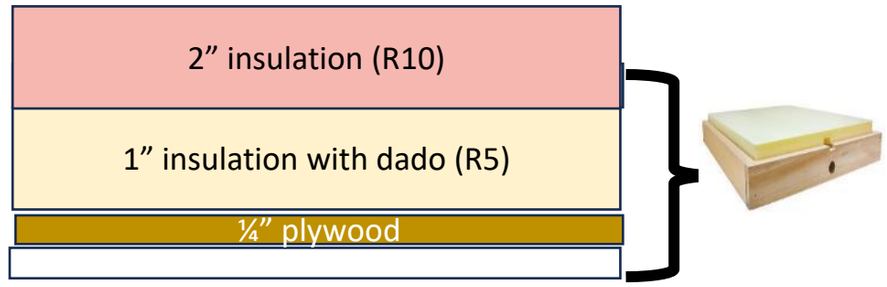
Before 2/27/24

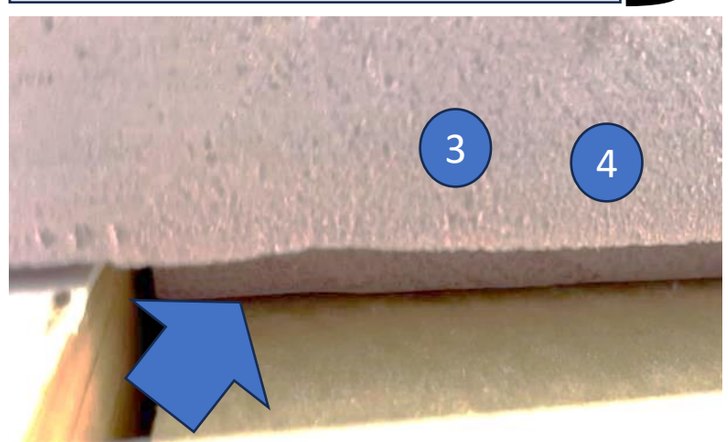






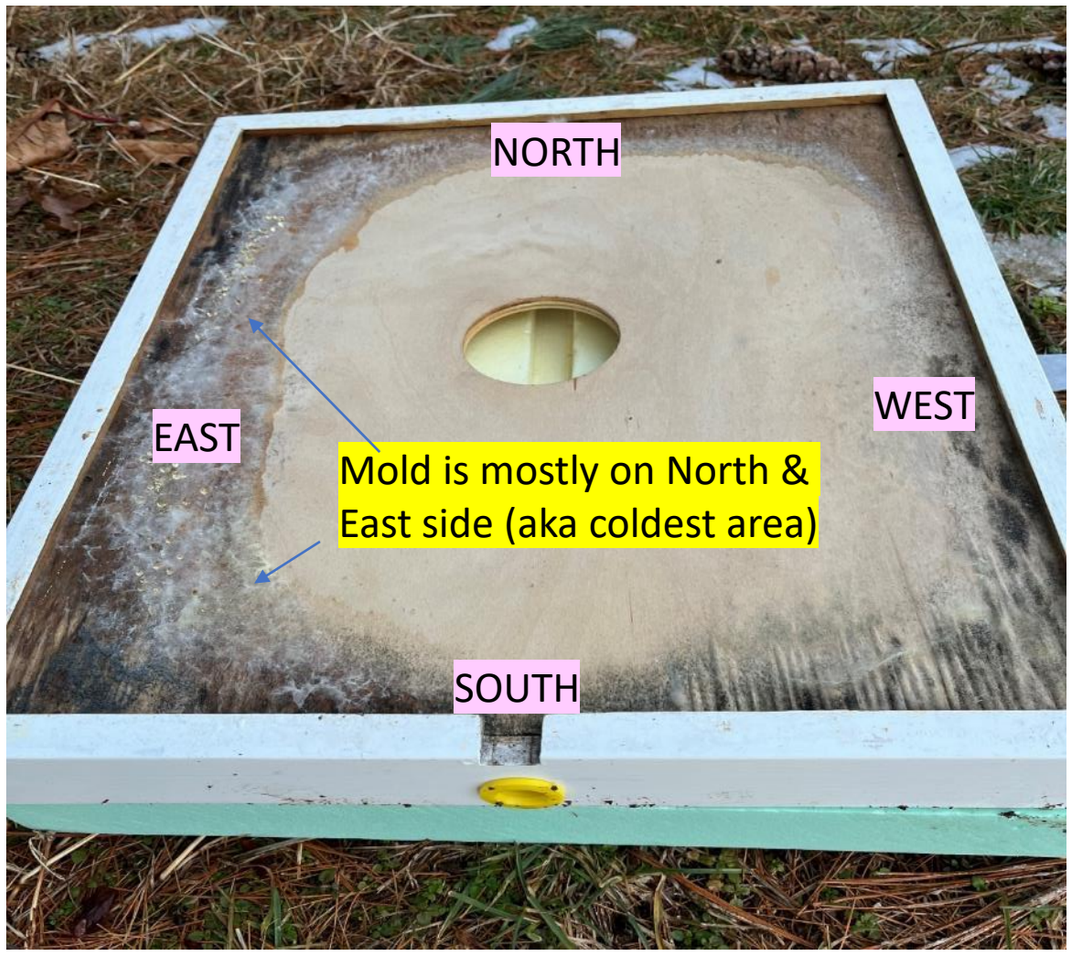
AFTER 2/27/24





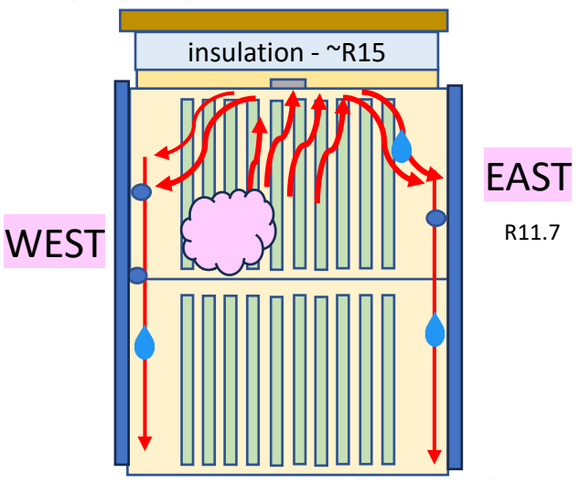
Was This Condensation a Problem or Did the Bees Take Advantage of It?

Top of Frames – under the inner cover



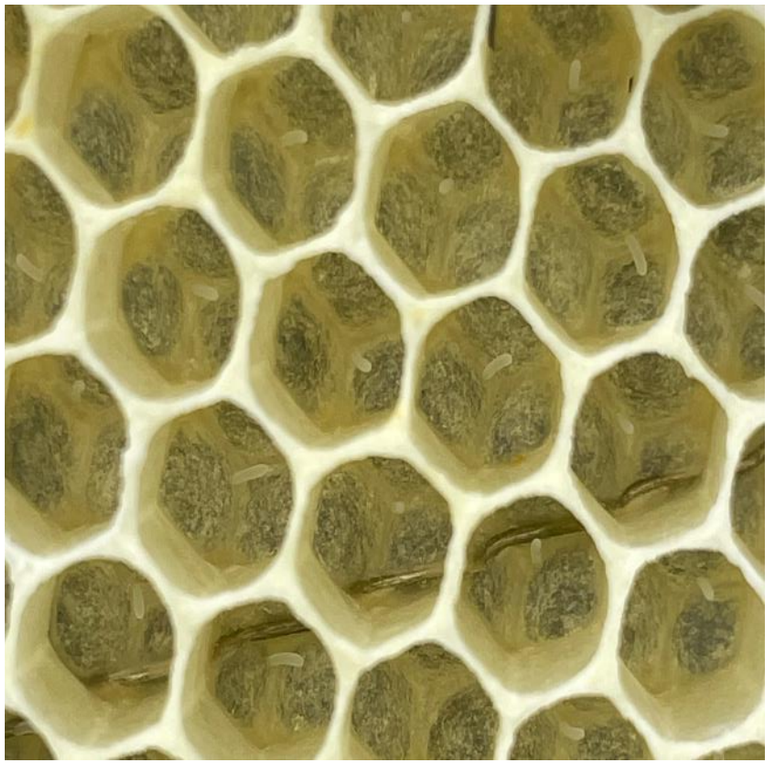
Underside of Mann Lake Inner Cover

- Moisture condensed on the coldest area of the colony
  - If there were no cold air spaces on the inner covers – it would have all condensed on the sidewalls.
- No moisture/mold on the Frames - Did the bees use it?
- RH in the 80s indicates - there was more moisture than the bees needed at this time. (Moisture weight = 0.85 lbs.), but later they may have used some of the moisture to breakdown food & managing RH for brood.



Bees were clustered down on the west side of the colony.

Bees Need 50-70% RH for Egg and Larva Development



- Eggs need relative humidity > 55% to hatch!
- Highest survival is 90-95% RH at the egg
- At 50% RH – many eggs shriveled

- At 50% RH – only 2.9% of eggs that hatched produced normal bees
- Nurse bees require moisture to produce royal jelly

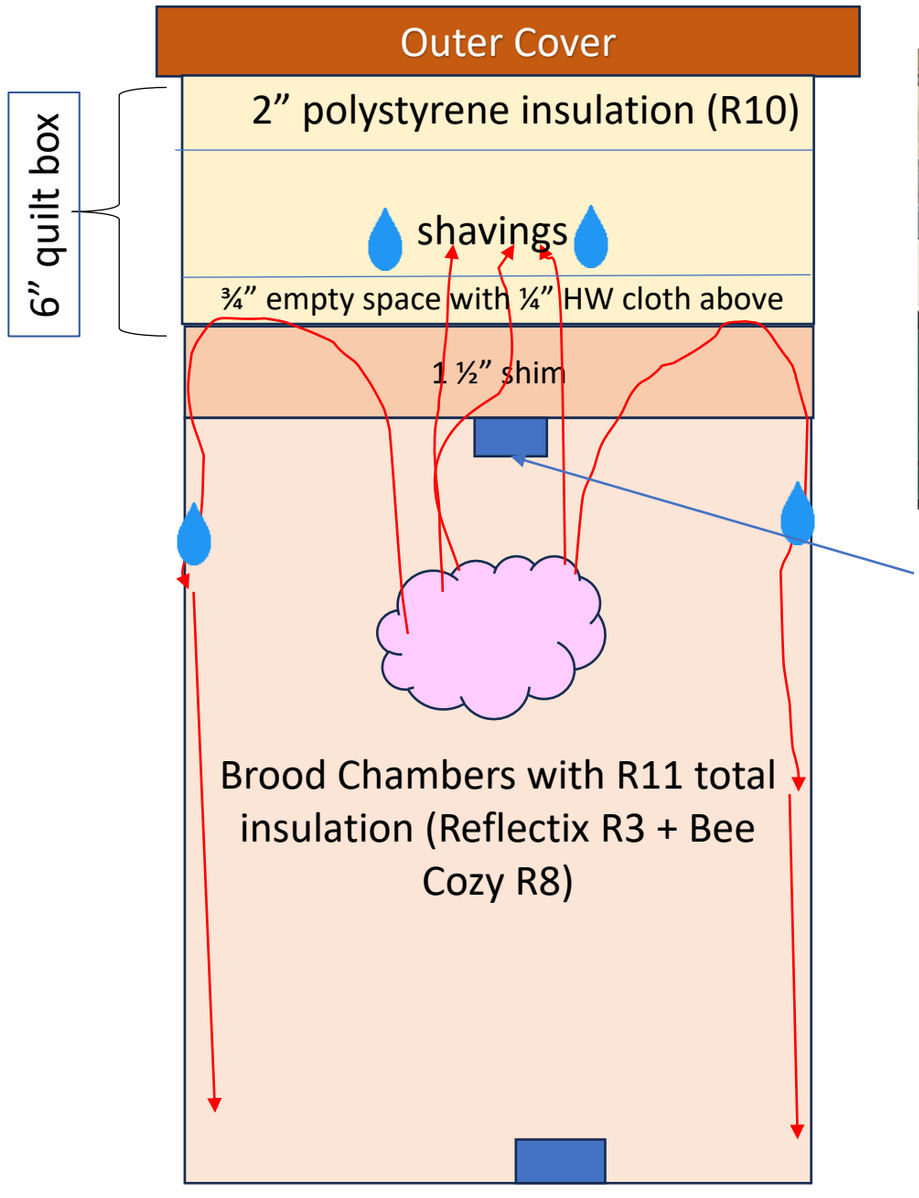
source: https://www.beeculture.com/a-closer-look-17/)

Quilt Boxes

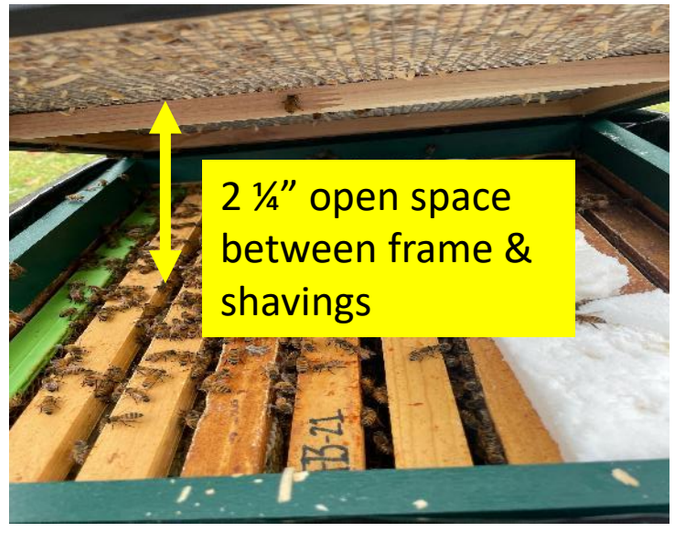
Shavings in the quilt box absorb excess moisture as the heat rises and moisture condenses.

Winter - check regularly to make sure the shavings are dry.

March – April – quilt boxes might absorb too much moisture - and bees can't keep the RH needed for brood.

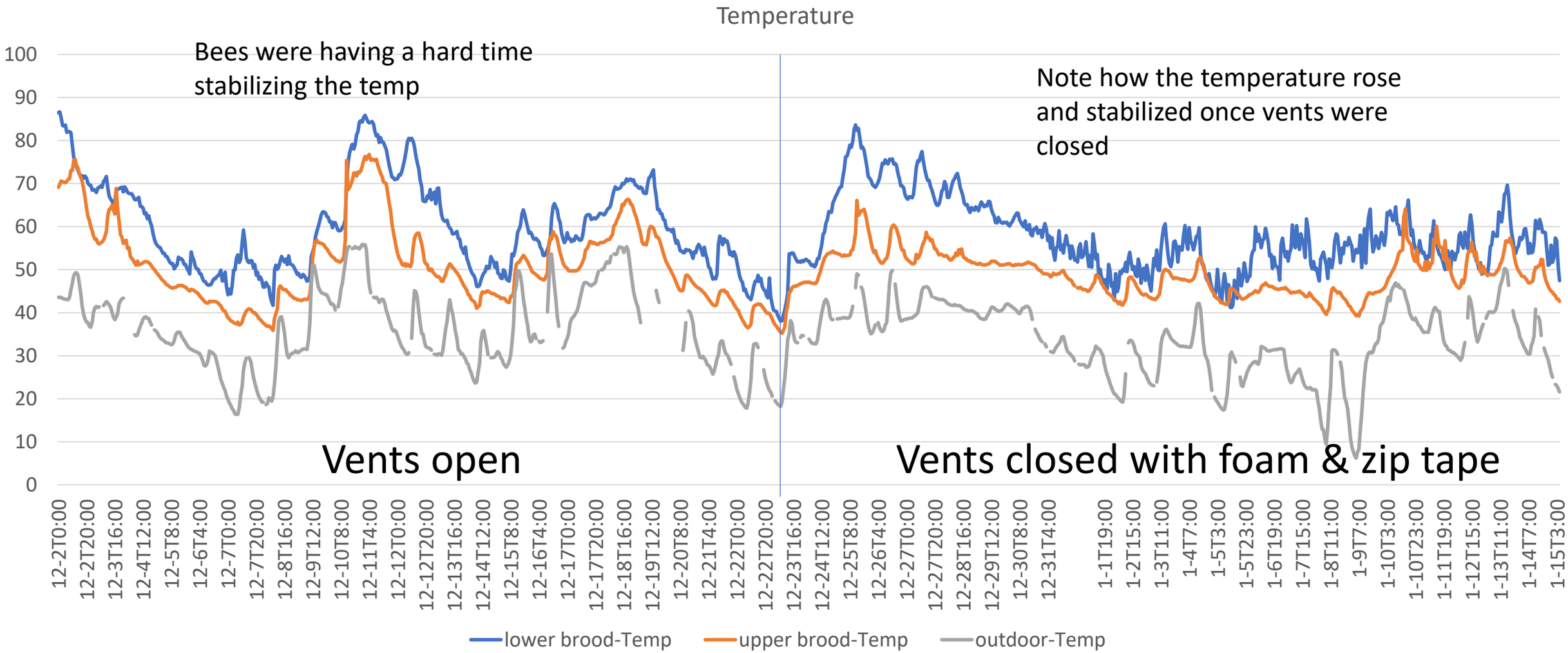


Temp/RH sensor



- quilt box has weather stripping on bottom to seal seam.

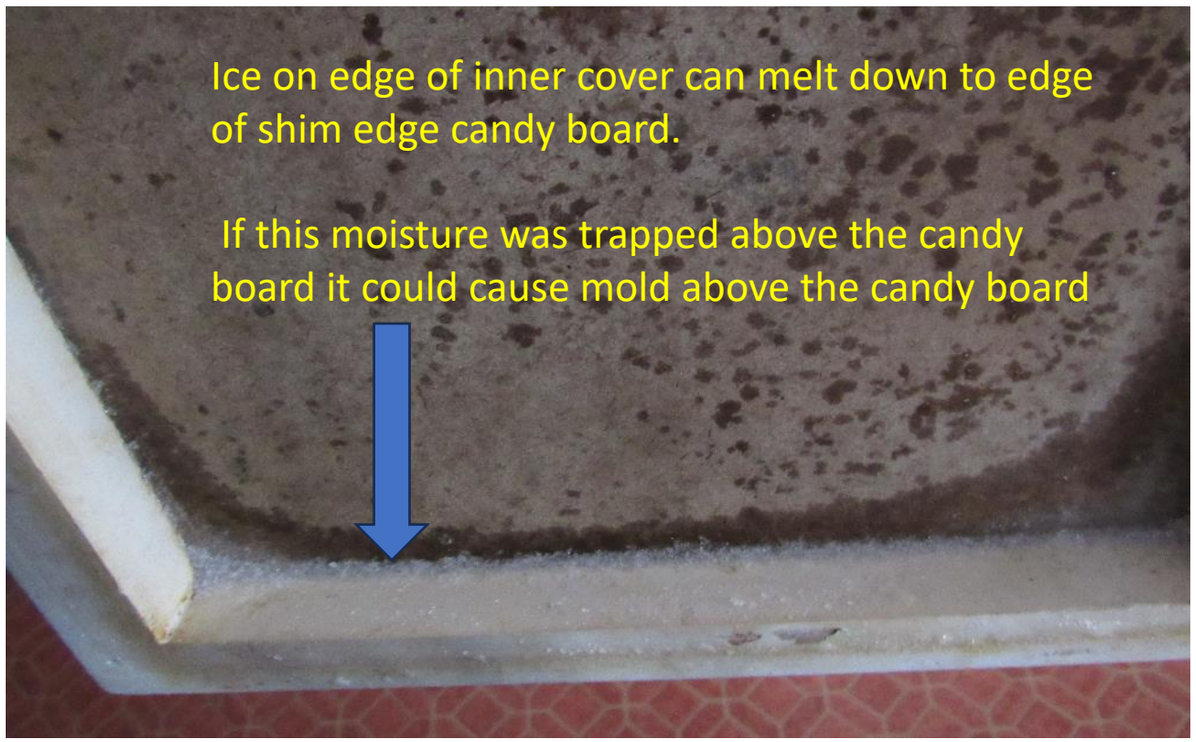
Quilt Boxes Can Have Too Much Venting



Moisture Collected in Quilt Box

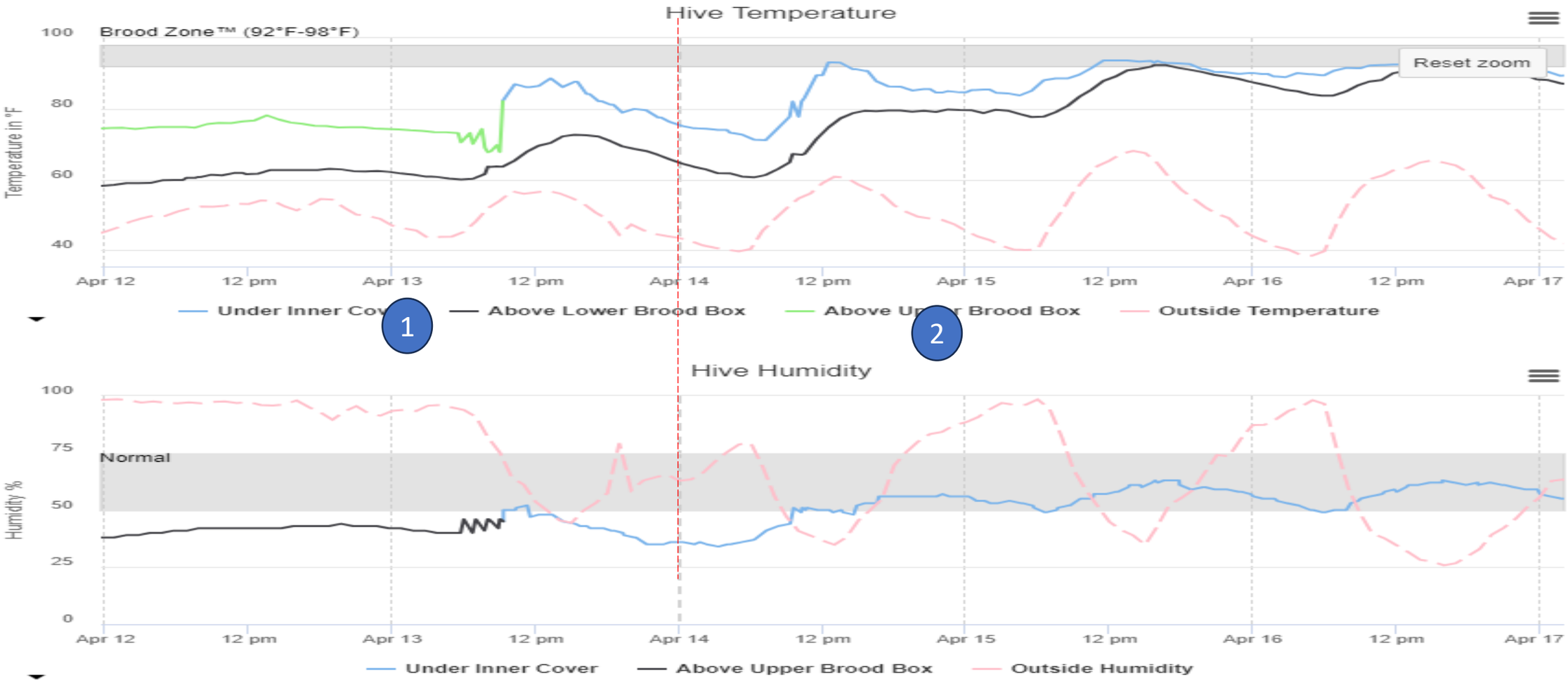
When relative humidity was 86% or higher, shavings were wet!

Wet shavings mean lower r-value.



It is a balancing act between having too much ventilation and too much moisture in a quilt box

Quilt Boxes Can Be Left On Too Long



Swapped quilt box & shim for 2” foil covered foam

Picture from Home Depot Website

1. Bees were trying to control the environment to raise brood, but the quilt box was probably absorbing too much moisture – but couldn’t before the quilt box was removed

2. Swapping quilt box for foam board allows bees to stabilize RH in the needed range

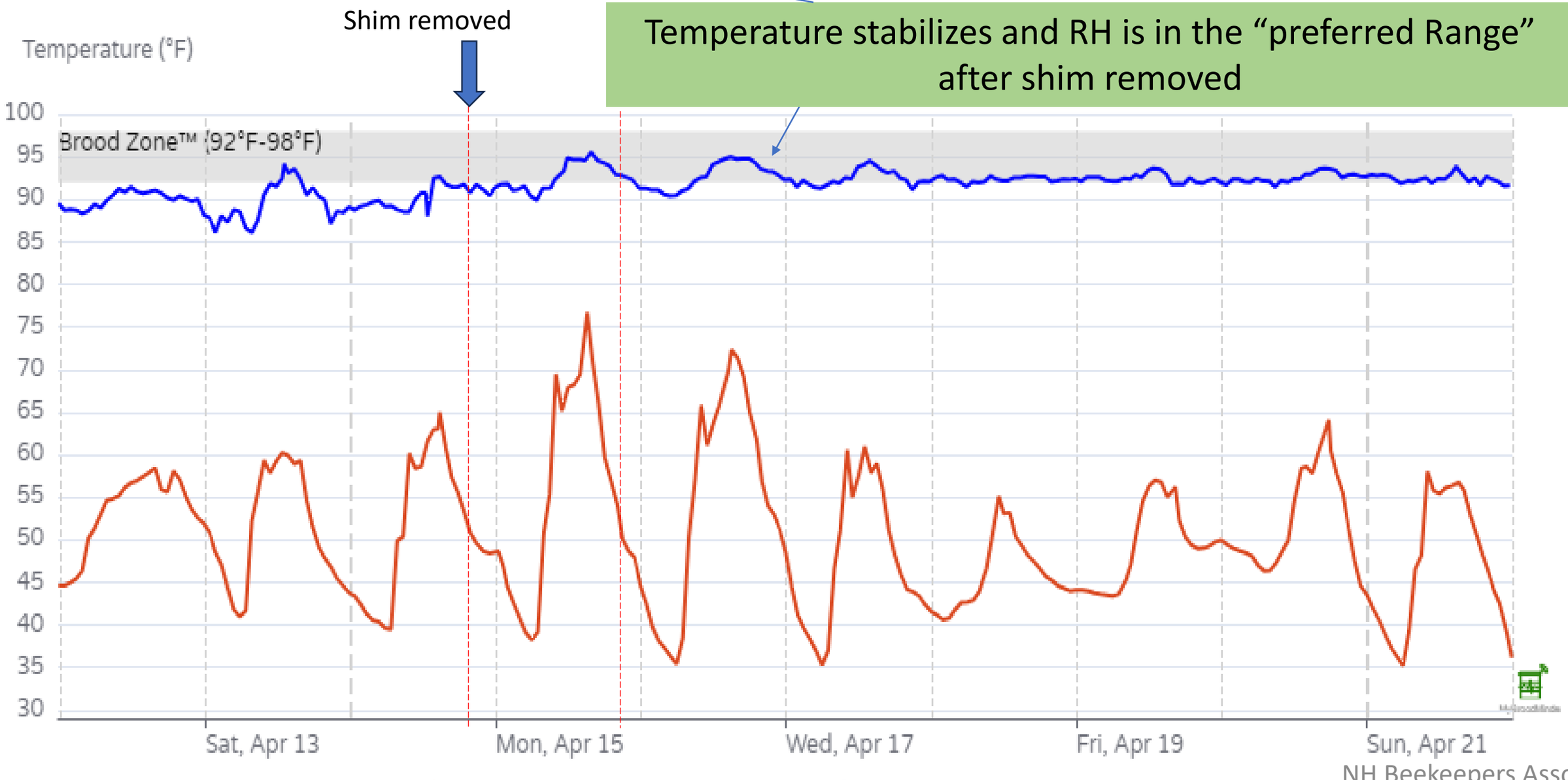
Effects of An Empty Feeding Shim

Empty Shims May Make Bees Work Harder

	Temperature	RH	VPD	
Lee 17 April 14 1:43 am	89.19	56	2.07	Reading before 1 1/2 shim removed
Lee 17 April 15 2:00 am	91.83	65	1.79	Reading after 1 1/2 shim removed

By reducing air space changes bees can better control Temp & RH for brood rearing.

Temperature stabilizes and RH is in the “preferred Range” after shim removed



Check Sensor RH Calibration!

Salt Test

Salt test is a way to check the calibration of your Relative Humidity Sensor

Steps:

- Make slurry of salt and water
- Put sensor in zip-lock bag with slurry for at least 24 hours
- Check RH reading – it should be ~ 75%

Source: https://www.wikihow.com/Test-a-Hygrometer

Results from our Tests

Sensor #	RH Offset
56:06:49	-24.0
56:06:4C	-12.5
56:06:48	-11.5
56:06:87	-11.0
56:06:43	-9.0
56:06:6E	-9.0
56:06:70	-9.0
56:06:6C	-8.0
56:06:CD	-8.0
56:06:4A	-7.0
56:06:6B	-7.0
56:06:3B	-6
56:06:42	-6.0
56:06:4B	-6.0
56:06:46	-5.5
56:01:79	-5.0
56:06:4E	-5.0
56:06:6D	-5.0
56:06:3F	-4
56:06:4D	-3.5
56:06:3D	-3
56:08:67	-3
56:06:40	-1
56:06:41	-1
56:06:3c	2

Sensor #	RH Offset
56:35:72	1.0
56:35:74	2.0
56:35:71	3.0
56:35:73	3.0
56:35:94	3.0
56:35:95	3.0
56:35:96	3.0
56:35:3A	5

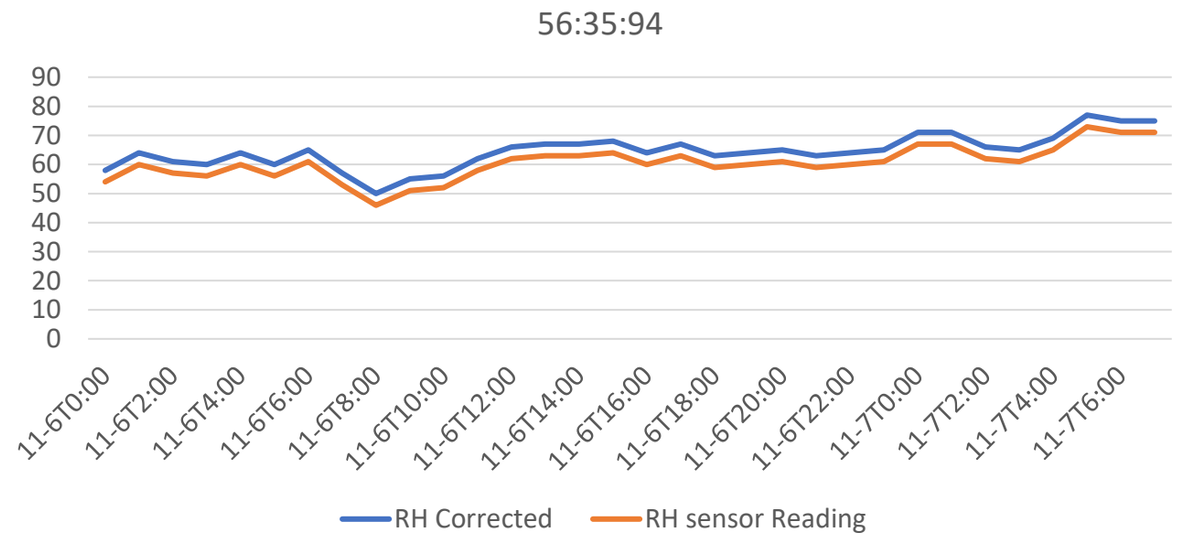
Sensor #	RH Offset
42:0D:4B	-0.5
42:0D:D6	-2.0

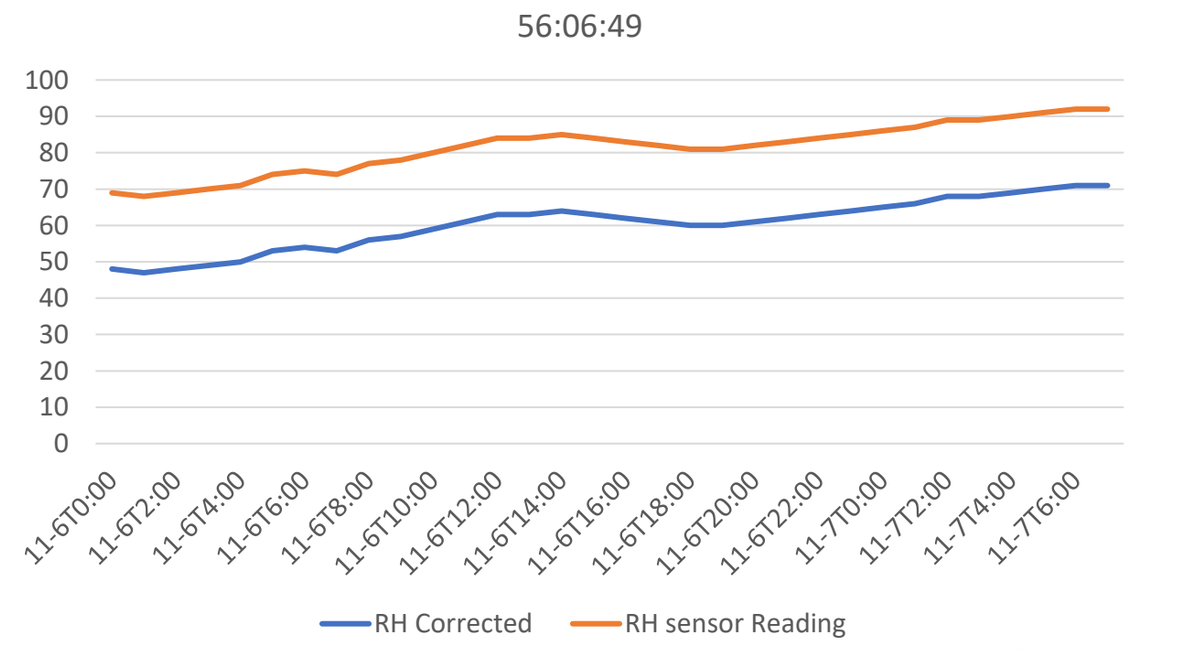
We are working with Broodminder to understand why we are seeing such variation

Why do we care?

False readings could lead to bad management decisions

- RH helps determine :
  - if we have moisture issues in non-brood rearing times
  - If brood is being reared





Source: https://www.wikihow.com/Test-a-Hygrometer

Updated VPD Table For Winter Colonies

Temp	Relative Humidity													
F	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
16	0.2031	0.1875	0.1719	0.1562	0.1406	0.1250	0.1094	0.0937	0.0781	0.0625	0.0469	0.0312	0.0156	0.0000
18	0.2215	0.2045	0.1874	0.1704	0.1533	0.1363	0.1193	0.1022	0.0852	0.0682	0.0511	0.0341	0.0170	0.0000
20	0.2413	0.2228	0.2042	0.1856	0.1671	0.1485	0.1299	0.1114	0.0928	0.0743	0.0557	0.0371	0.0186	0.0000
22	0.2627	0.2425	0.2223	0.2021	0.1819	0.1617	0.1415	0.1213	0.1011	0.0808	0.0606	0.0404	0.0202	0.0000
24	0.2858	0.2638	0.2418	0.2199	0.1979	0.1759	0.1539	0.1319	0.1099	0.0879	0.0660	0.0440	0.0220	0.0000
26	0.3107	0.2868	0.2629	0.2390	0.2151	0.1912	0.1673	0.1434	0.1195	0.0956	0.0717	0.0478	0.0239	0.0000
28	0.3374	0.3115	0.2855	0.2596	0.2336	0.2076	0.1817	0.1557	0.1298	0.1038	0.0779	0.0519	0.0260	0.0000
30	0.3662	0.3380	0.3099	0.2817	0.2535	0.2254	0.1972	0.1690	0.1409	0.1127	0.0845	0.0563	0.0282	0.0000
32	0.3972	0.3666	0.3361	0.3055	0.2749	0.2444	0.2138	0.1833	0.1528	0.1222	0.0917	0.0611	0.0305	0.0000
34	0.4304	0.3973	0.3642	0.3311	0.2980	0.2648	0.2317	0.1986	0.1655	0.1324	0.0993	0.0662	0.0331	0.0000
36	0.4660	0.4302	0.3943	0.3585	0.3226	0.2868	0.2509	0.2151	0.1792	0.1434	0.1075	0.0717	0.0358	0.0000
38	0.5043	0.4655	0.4267	0.3879	0.3491	0.3103	0.2715	0.2328	0.1940	0.1552	0.1164	0.0776	0.0388	0.0000
40	0.5453	0.5034	0.4614	0.4195	0.3775	0.3356	0.2936	0.2517	0.2097	0.1678	0.1258	0.0839	0.0419	0.0000
42	0.5892	0.5439	0.4986	0.4533	0.4079	0.3626	0.3173	0.2720	0.2266	0.1813	0.1360	0.0907	0.0453	0.0000
44	0.6363	0.5873	0.5384	0.4894	0.4405	0.3916	0.3426	0.2937	0.2447	0.1958	0.1468	0.0979	0.0489	0.0000
46	0.6866	0.6338	0.5809	0.5281	0.4753	0.4225	0.3697	0.3169	0.2641	0.2113	0.1584	0.1056	0.0528	0.0000
48	0.7404	0.6834	0.6265	0.5695	0.5126	0.4556	0.3987	0.3417	0.2848	0.2278	0.1709	0.1139	0.0570	0.0000
50	0.7978	0.7364	0.6751	0.6137	0.5523	0.4910	0.4296	0.3682	0.3069	0.2455	0.1841	0.1227	0.0614	0.0000
52	0.8592	0.7931	0.7270	0.6609	0.5948	0.5287	0.4626	0.3965	0.3305	0.2644	0.1983	0.1322	0.0661	0.0000
54	0.9246	0.8535	0.7824	0.7113	0.6401	0.5690	0.4979	0.4268	0.3556	0.2845	0.2134	0.1423	0.0711	0.0000
56	0.9945	0.9180	0.8415	0.7650	0.6885	0.6120	0.5355	0.4590	0.3825	0.3060	0.2295	0.1530	0.0765	0.0000
58	1.0689	0.9867	0.9044	0.8222	0.7400	0.6578	0.5756	0.4933	0.4111	0.3289	0.2467	0.1644	0.0822	0.0000
60	1.1482	1.0598	0.9715	0.8832	0.7949	0.7066	0.6182	0.5299	0.4416	0.3533	0.2650	0.1766	0.0883	0.0000
62	1.2325	1.1377	1.0429	0.9481	0.8533	0.7585	0.6637	0.5689	0.4741	0.3792	0.2844	0.1896	0.0948	0.0000
64	1.3223	1.2206	1.1189	1.0172	0.9155	0.8137	0.7120	0.6103	0.5086	0.4069	0.3052	0.2034	0.1017	0.0000
66	1.4178	1.3087	1.1997	1.0906	0.9816	0.8725	0.7634	0.6544	0.5453	0.4362	0.3272	0.2181	0.1091	0.0000
68	1.5193	1.4024	1.2855	1.1687	1.0518	0.9349	0.8181	0.7012	0.5843	0.4675	0.3506	0.2337	0.1169	0.0000
70	1.6270	1.5019	1.3767	1.2516	1.1264	1.0012	0.8761	0.7509	0.6258	0.5006	0.3755	0.2503	0.1252	0.0000
72	1.7414	1.6075	1.4735	1.3396	1.2056	1.0716	0.9377	0.8037	0.6698	0.5358	0.4019	0.2679	0.1340	0.0000
74	1.8628	1.7195	1.5762	1.4329	1.2896	1.1463	1.0031	0.8598	0.7165	0.5732	0.4299	0.2866	0.1433	0.0000
76	1.9915	1.8383	1.6851	1.5319	1.3788	1.2256	1.0724	0.9192	0.7660	0.6128	0.4596	0.3064	0.1532	0.0000
78	2.1280	1.9643	1.8006	1.6369	1.4732	1.3095	1.1458	0.9821	0.8184	0.6548	0.4911	0.3274	0.1637	0.0000
80	2.2725	2.0977	1.9229	1.7481	1.5733	1.3984	1.2236	1.0488	0.8740	0.6992	0.5244	0.3496	0.1748	0.0000
82	2.4255	2.2389	2.0523	1.8658	1.6792	1.4926	1.3060	1.1195	0.9329	0.7463	0.5597	0.3732	0.1866	0.0000
84	2.5874	2.3884	2.1894	1.9903	1.7913	1.5923	1.3932	1.1942	0.9952	0.7961	0.5971	0.3981	0.1990	0.0000

Red = brood present (Lighter pink shows brood present but bees need to add/remove moisture)

Yellow = If Dec-Feb, cluster is very close to sensor; If March/April - cluster is near by not at sensor.

Green = getting some heat from cluster

Blue = away from cluster. Could have condensation present but may not

White = On the line between the color above and below

Still More Questions to be Answered

- Do the colonies that create their own entrances have something in common?
- Do Empty Feeding Shims make the bees work harder?
- Bees will propolize feeder and other holes to block air but how much does it really insulate? How much heat & moisture still transfers through these holes?
  - Feedback Dr Derek Mitchell:
    - *"The thickness (~1mm) and compostion (solid tree resins) of propolis means it is completely insignificant for insulation even in wooden hives. It has a greater effect is on water vapour."*
    - *"It probably acts like a vapour retarding barrier. Though this is an extrapolation of the properties of tree resins. There has been very little research into the physical properties of propolis itself."*
  - Feedback from Randy Oliver:
    - *"Propolis is used by the bees for varnishing and caulking their nest cavities -- it would have nearly zero insulating value."*
    - *"Yes, the bees use propolis as a water barrier, which during the winter results in water vapor condensing on the surface of the propolis lining of the nest cavity, rather than being absorbed into the wood. This provides bees with liquid water when it's too cold for the water foragers to fly. But this then brings up one negative effect of too much side insulation -- lack of accessible condensate for the thirsty bees"*
    - *We hot-dip all of our woodenware in a mixture of paraffin and pine rosin, to provide a similar internal waterproof seal for the bees' benefit.*

THINGS TO REMEMBER

BEES NEED 50-70% RH FOR EGGS TO MATURE & MOISTURE TO MAKE ROYAL JELLY

BEES DO A GOOD JOB AT CONTROLLING THEIR ENVIRONMENT

BEES NEED MOISTURE TO BREAKDOWN WINTER FEED

ANY DISTURBANCE WILL MAKE THE BEES BREAK CLUSTER

LEAVING MOISTURE SYSTEMS ON TOO LONG CAN MAKE IT DIFFICULT FOR BEES TO MAINTAIN RH FOR BROOD

GAPS MATTER! MOISTURE MAY COLLECT WHERE YOU DON'T WANT IT!

TEST YOUR SENSORS!

References

- **Brood RH requirements:**
  - https://www.beeculture.com/a-closer-look-17/)
  - **https://scientificbeekeeping.com/observations-on-pollen-subs-part-4-nectar-water-and-humidity/**
- **Water Collection at low temps:**
  - **https://www.researchgate.net/publication/323112409_Cold_flying_foragers_Honey_bees_in_Scotland_seek_water_in_winter**

BACKGROUND

Final version of insulation in Mann Lake Cover