# New Insights into Natural Aeration Grain Drying Systems

IHARF Winter Seminar

Melville Communiplex

February 1, 2012  11:00 AM

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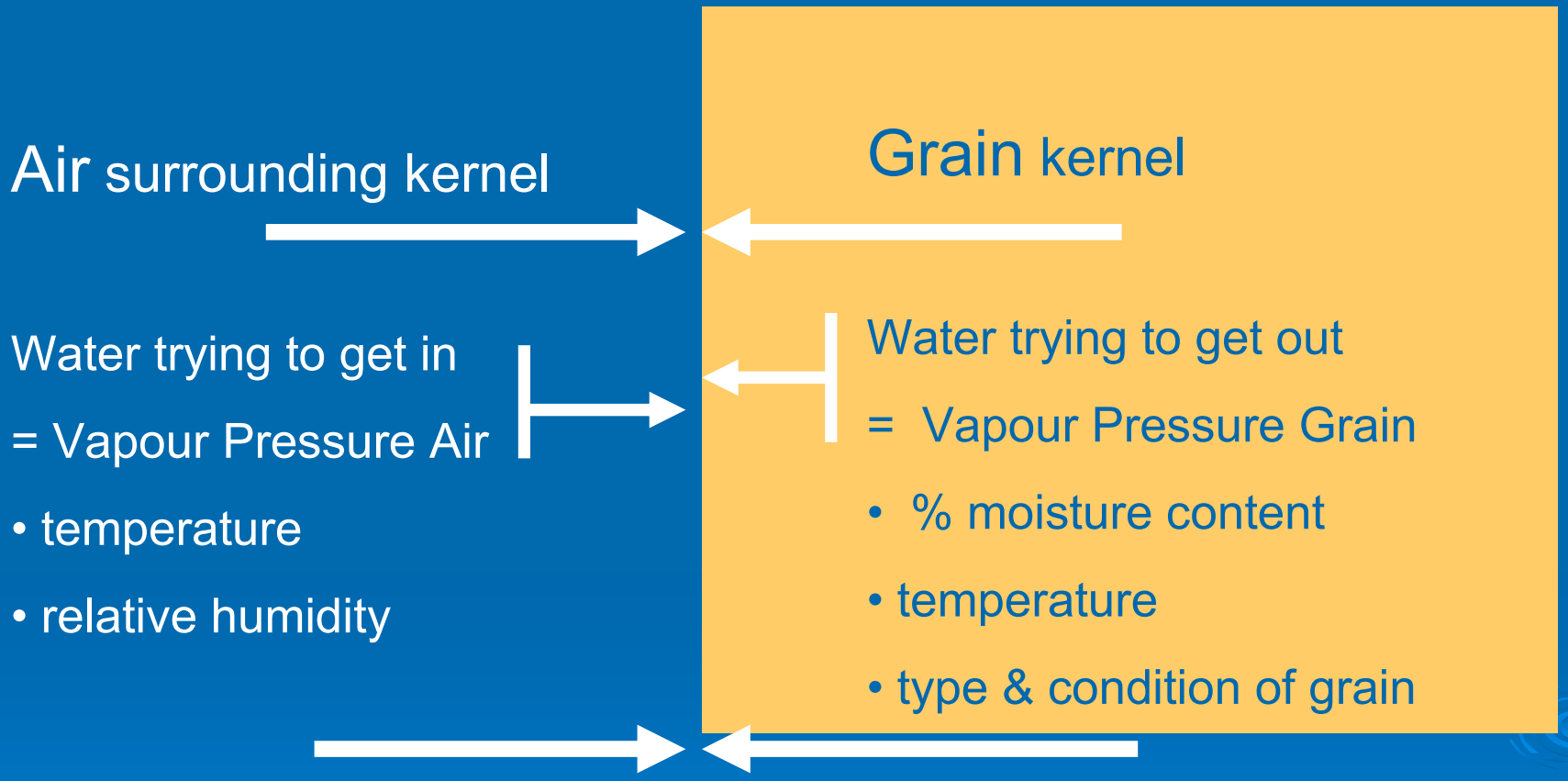
# Objective

- To build a fan controller that:
  - is **Efficient** – saves power, fan on only when necessary (if drying fan on, if not drying fan off)
  - Provides **Safe** Grain Storage – i.e.. No spoilage
    - **Cool** grain
    - **Dry** grain

## Strategy

Only run the fan when ambient air conditions will result in drying of the grain; but, that's the question: how do we know what conditions will produce *drying* and what conditions will produce no drying or even *wetting*?

# Vapour Pressure



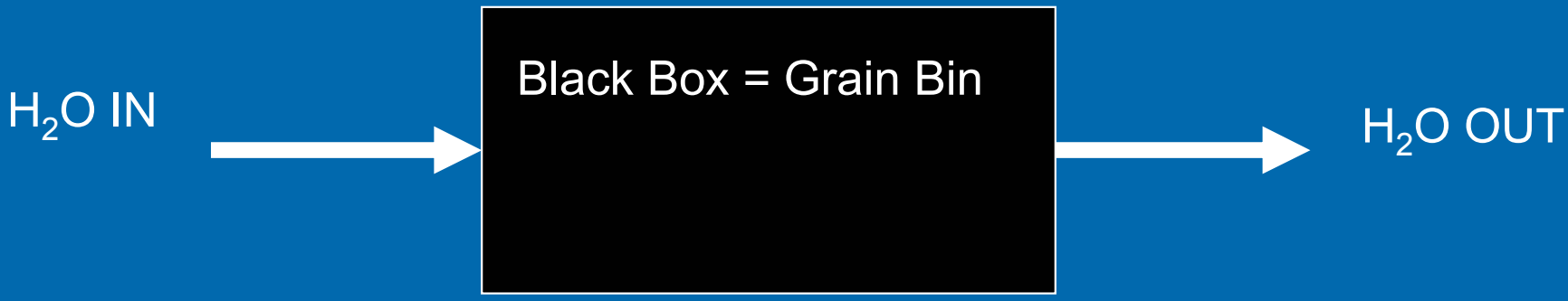

When air vapour pressure is greater than grain vapour pressure, water enters the grain and WETTING occurs. When Vps are equal, → EMC

When grain vapour pressure is greater than the air vapour pressure, water evaporates from the grain into the air and we have DRYING

# Controller – Vapour Pressure?

- Fan ON only if  VP grain > VP air
- This is not practical because:
  - Although VP air is easy to determine from temperature and relative humidity; it varies across the bin
  - VP grain can not be measured directly, and it too varies across the bin.
  - We need another approach

# The Black Box Approach




If $H_2O$ OUT > $H_2O$ IN then FAN ON (drying)

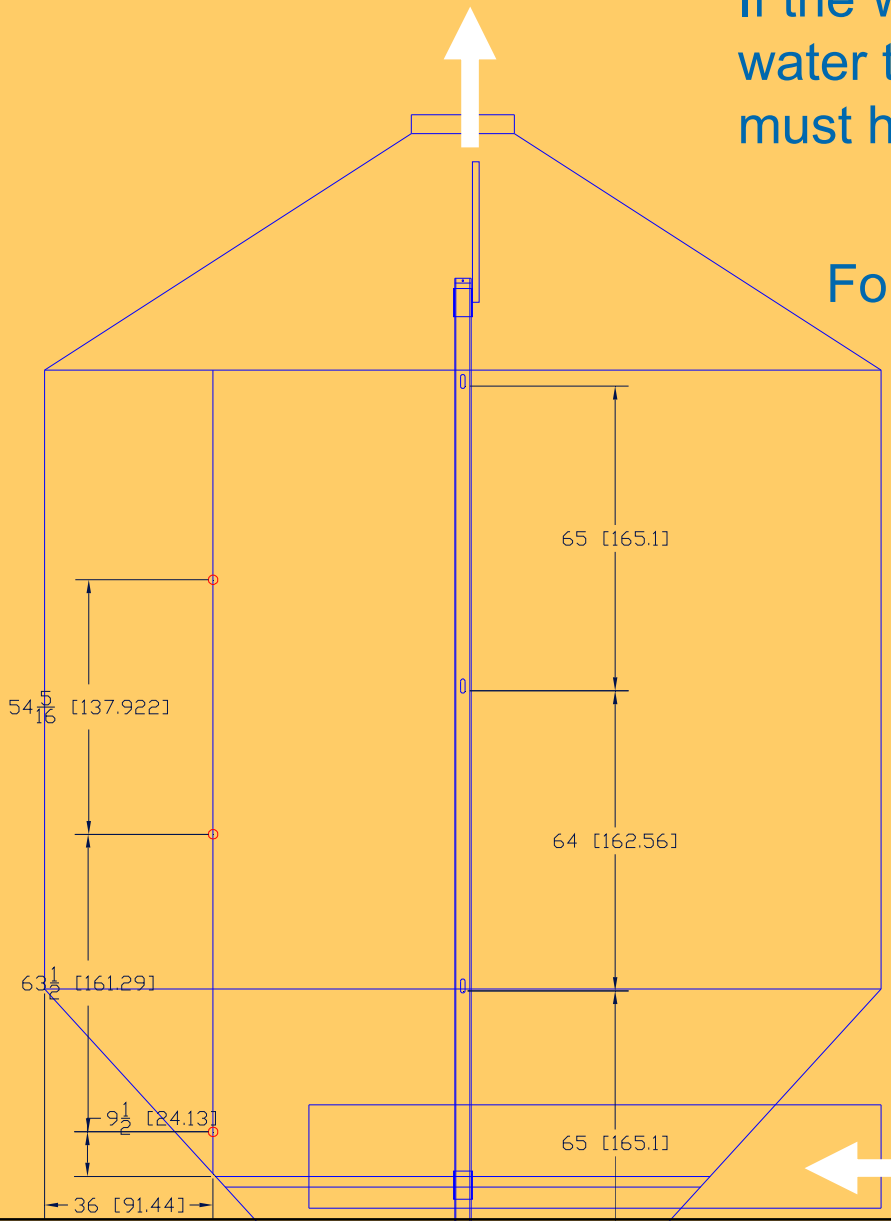
If $H_2O$ IN > $H_2O$ OUT then FAN OFF (wetting)

## lbs Water OUT – lbs Water IN = Water Removed

If the Water Removed is positive, then this is the amount of water that must have come from the grain and therefore we are DRYING

If the Water Removed is negative, ie there is more water that went in than came out; then the water must have gone into the grain :: WETTING

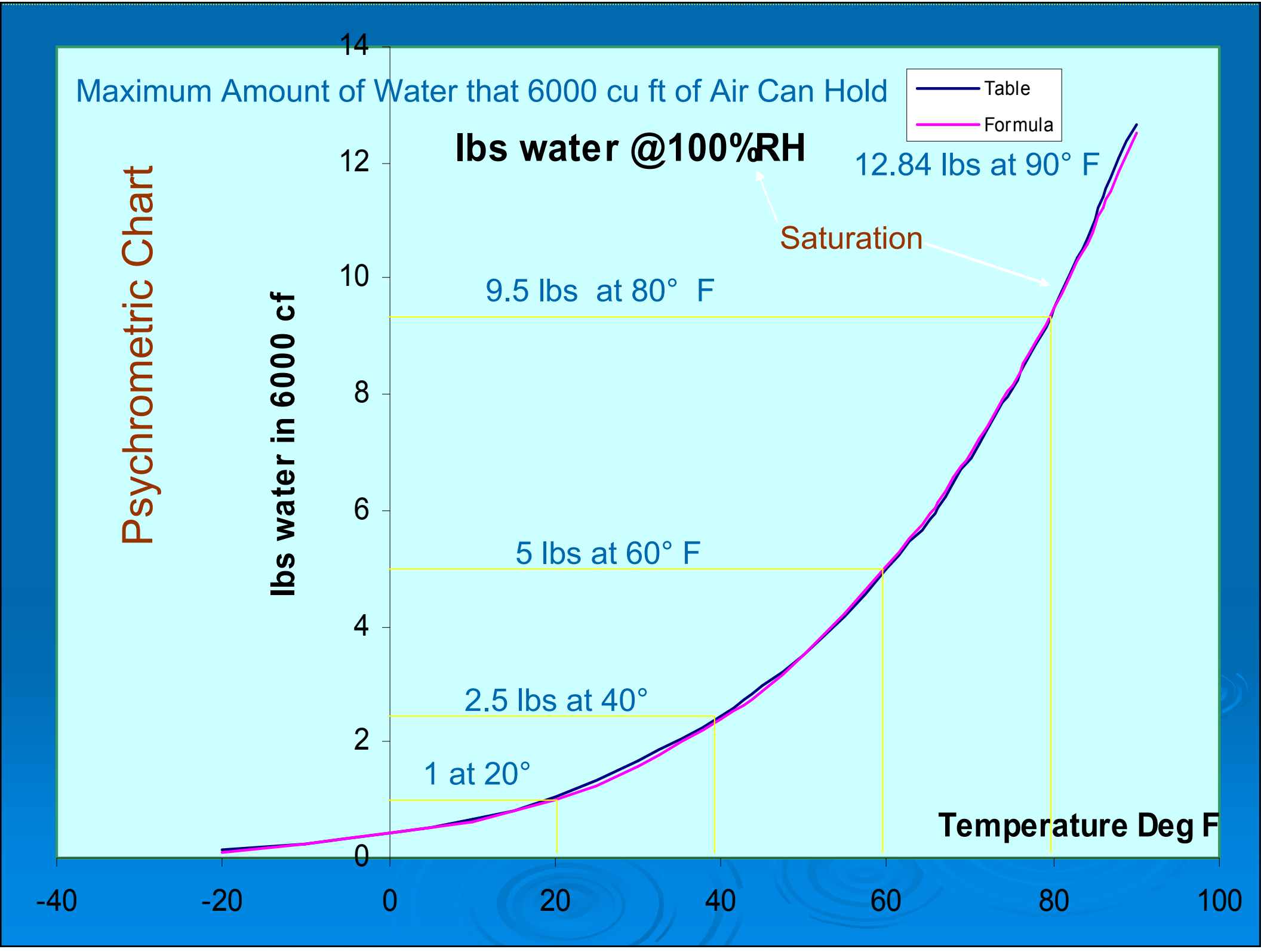
Water OUT



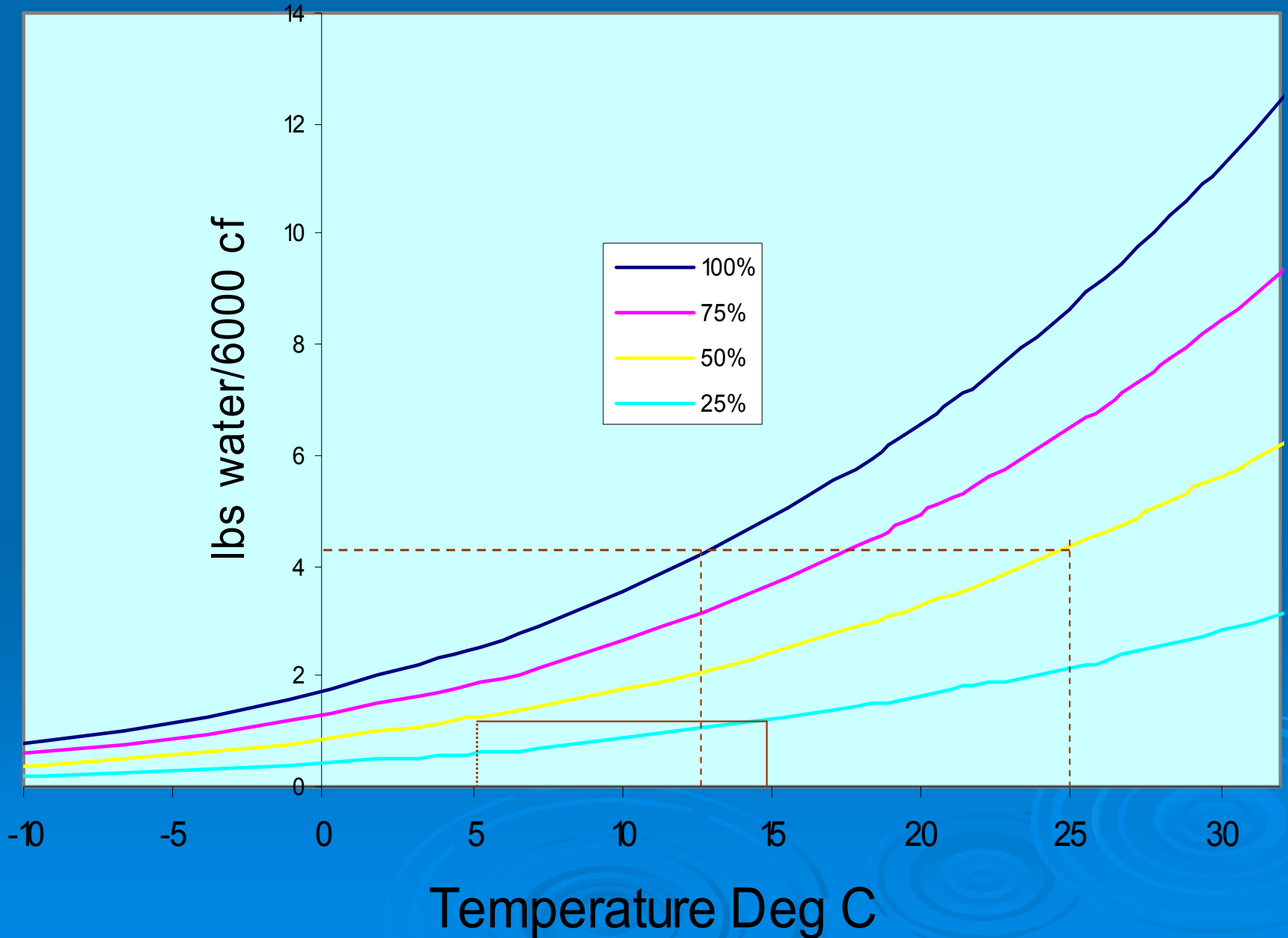

For example: let's say that in one hour we measured 80 lbs of water going into the bin and 90 lbs of water coming out. The net result is 10 lbs of water being removed from the bin. And it must have come from the grain, so we are drying.

But how do we measure the amount of water going in and out?
How much water is the air carrying?

Water IN (carried in by the air)

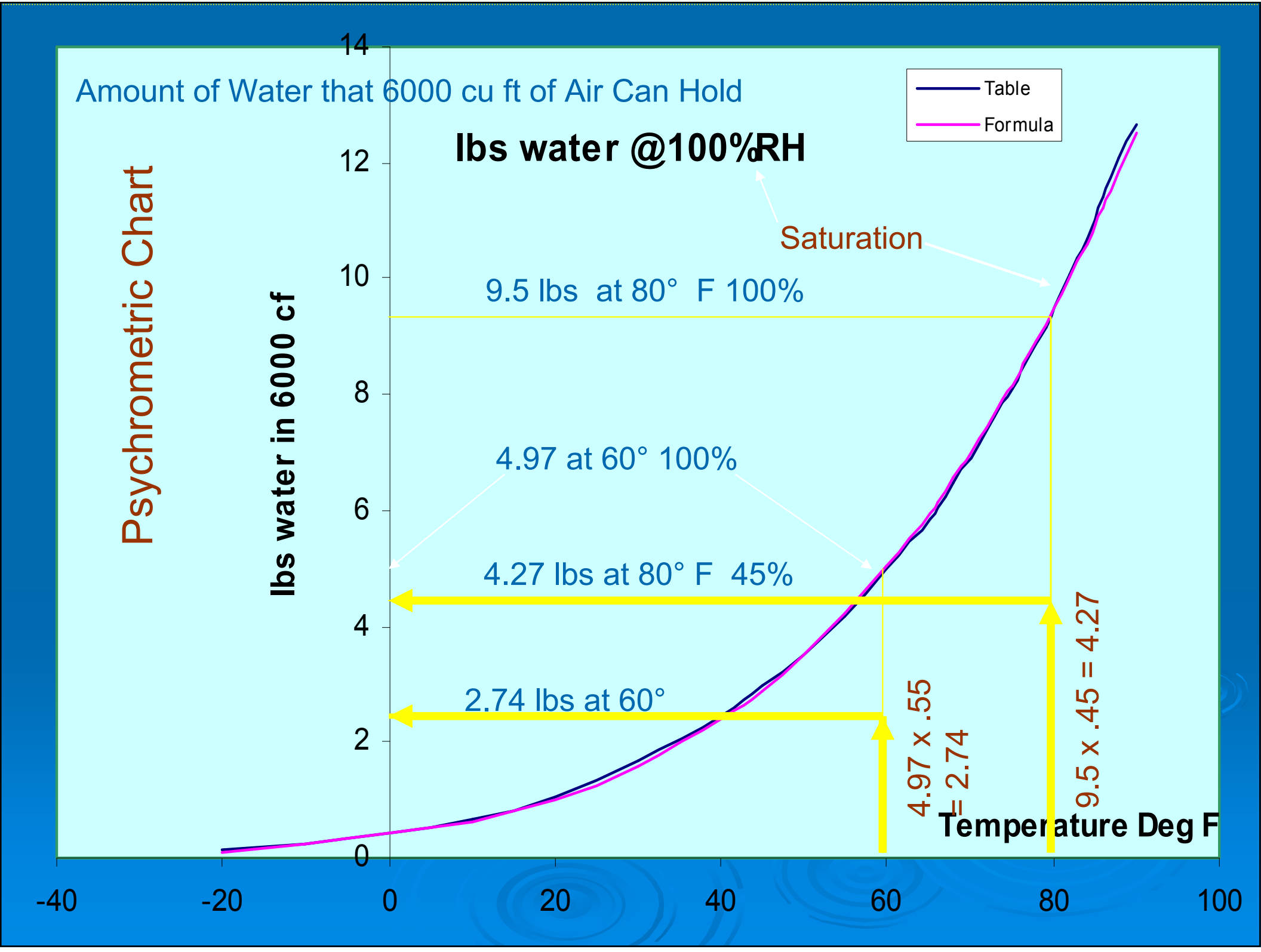

Maximum Amount of Water that 6000 cu ft of Air Can Hold
Psychrometric Chart
lbs water @100%RH
12.84 lbs at 90° F
Saturation
9.5 lbs at 80° F
5 lbs at 60° F
2.5 lbs at 40°
1 at 20°
lbs water in 6000 cf
Temperature Deg F
Table
Formula
14
12
10
8
6
4
2
0
-40
-20
0
20
40
60
80
100

# Water Holding Capacity

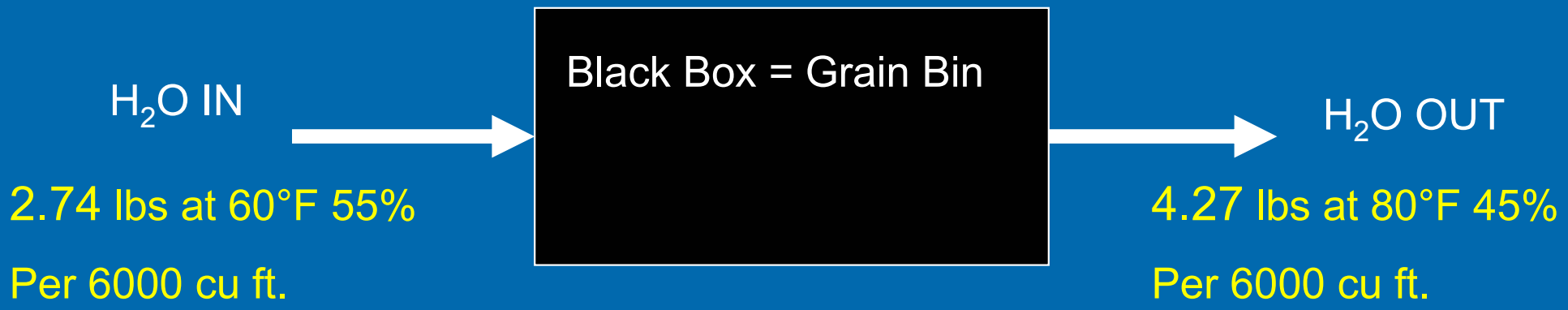


# $H_2O$ IN/OUT Example

- We have a 2000 bu bin with an aeration fan with a flow of 3000 cfm. The air going into the fan and into the bin is 60° F @ 55% RH. The air leaving the bin is 80° F @ 45% RH. Are we drying? How much?
- From the previous psychrometric chart for 6000 cu ft, 80° @ 45% = 4.27 lbs $H_20$ ->air
  6000 cu ft, 60° @ 55% = 2.74 lbs
- Every 2 min remove 1.53 lbs ::(drying)


Amount of Water that 6000 cu ft of Air Can Hold
Psychrometric Chart
lbs water @100%RH
Table
Formula
Saturation
9.5 lbs at 80° F 100%
4.97 at 60° 100%
4.27 lbs at 80° F 45%
2.74 lbs at 60°
4.97 x .55 = 2.74
9.5 x .45 = 4.27
lbs water in 6000 cf
Temperature Deg F
14
12
10
8
6
4
2
0
-40
-20
0
20
40
60
80
100

# The Black Box Approach



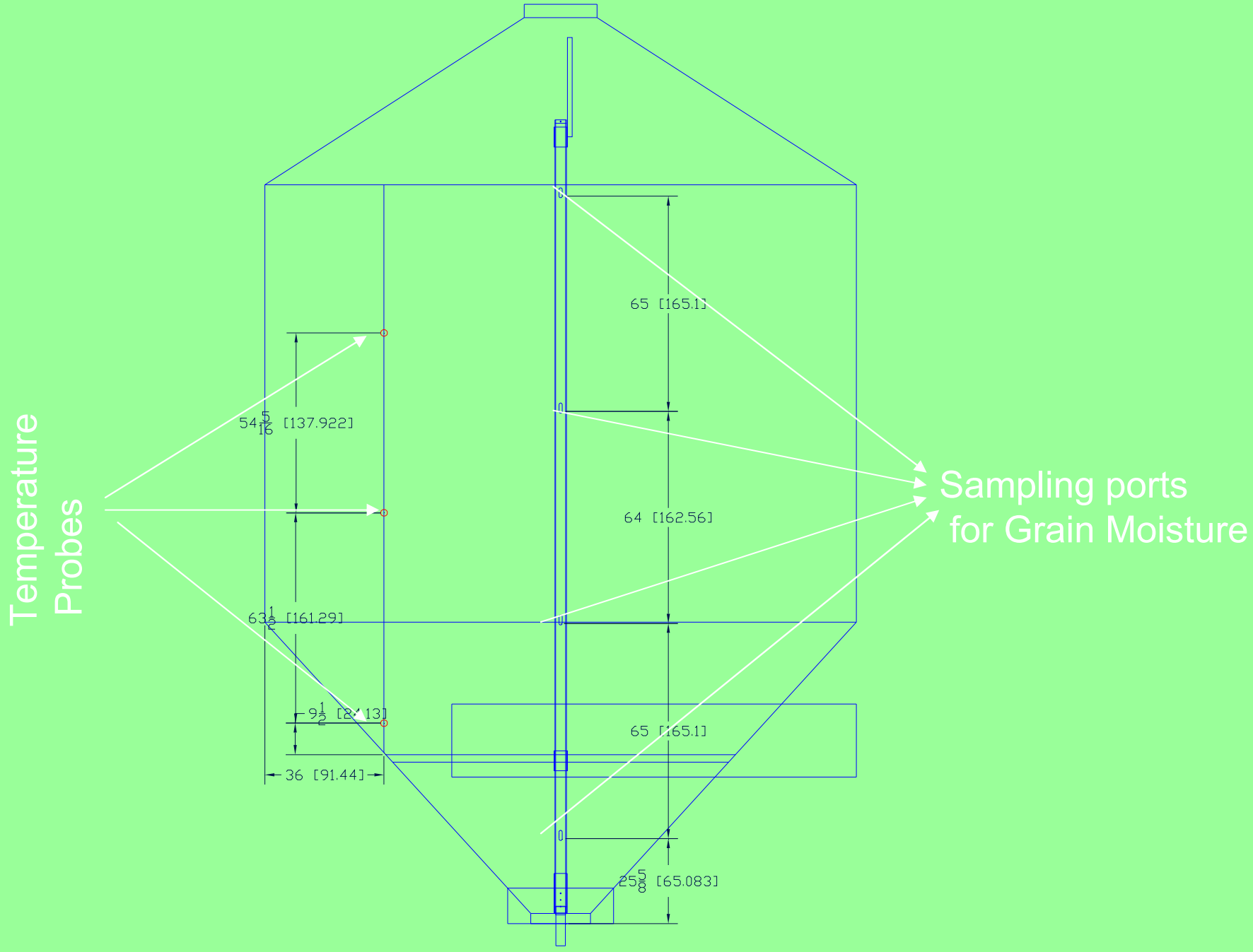

If $H_2O$ OUT > $H_2O$ IN then FAN ON (drying)

4.27 lbs > 2.74 lbs → FAN On (1.53lbs/6000)

Fan 3000 cfm or 6000 cu ft/2 min → 46 lbs/hr drying

# What we did

- Instrumented Two Bins and measured on an hourly basis:
- Temp and Humidity – air in and out
- Air Flow
- Temp of Grain at three levels
- On a daily basis measured grain moisture at 4 levels
- Have done this for 4 years with 3 different grains – peas, barley, and wheat


Temperature Probes
Sampling ports for Grain Moisture
65 [165.1]
64 [162.56]
65 [165.1]
36 [91.44]


Panel with Instruments


Air Tubes for Recording CFM

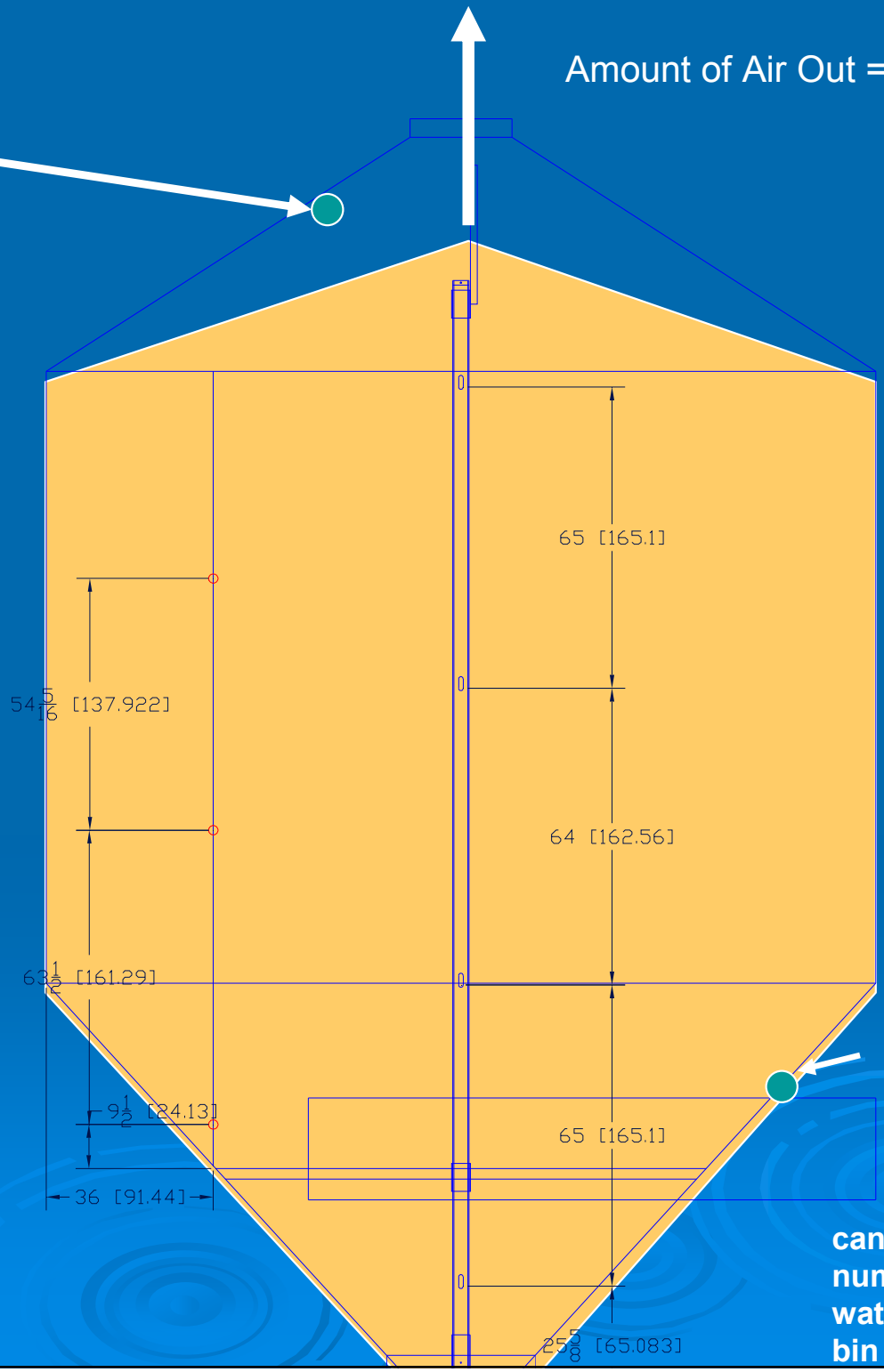

RH and Temperature Probe
On Inside Top of Bin Recording
RH and T°.


Inside the Panel

**Sensor measuring T and RH of the air leaving the bin**

**Therefore we know the temp & RH of the air leaving the bin, and we can calculate the number of lbs of water leaving the bin per hour**

Amount of Air Out = Amount of Air In



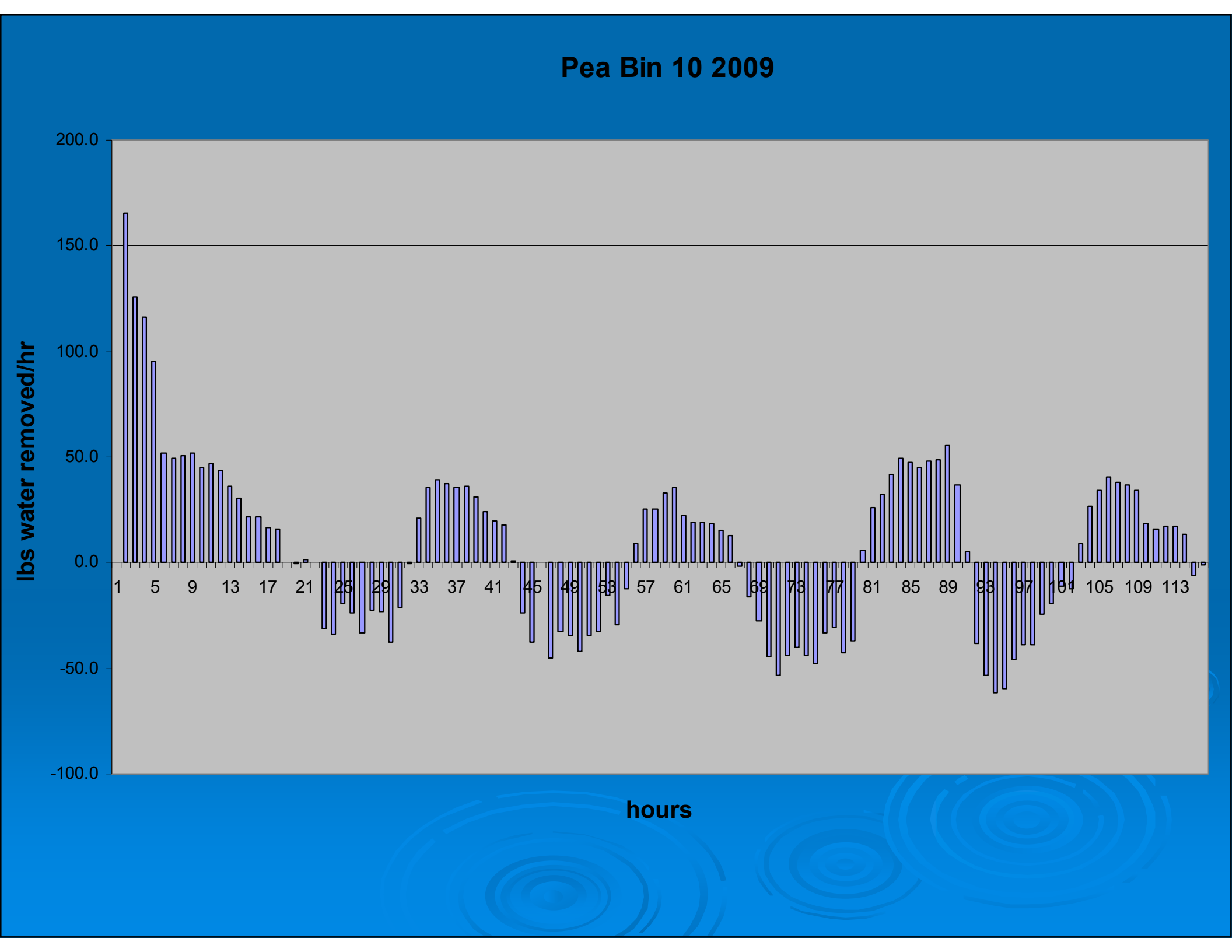

**Sensor measuring T and RH of the air entering the bin**

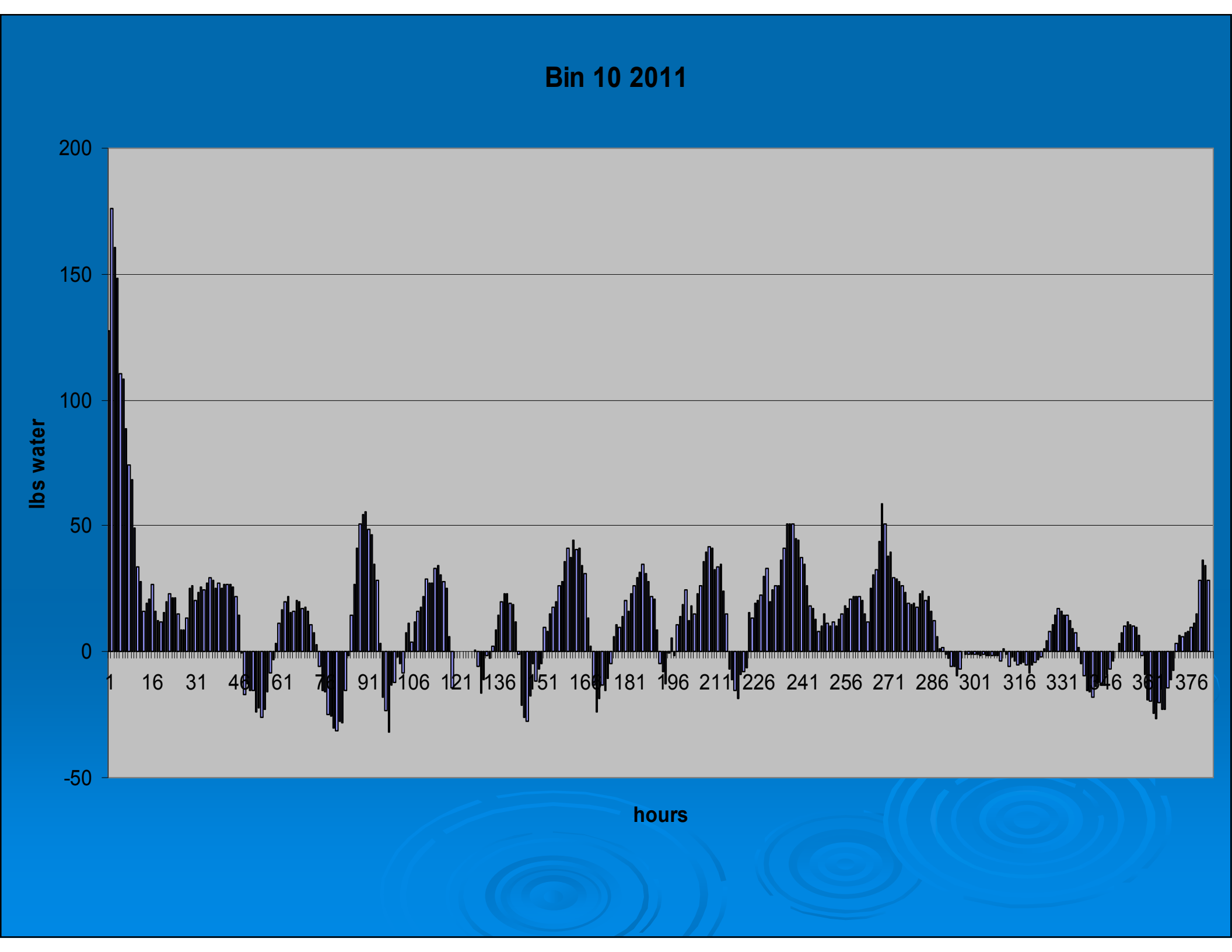
**can calculate the number of lbs of water entering the bin per hour**

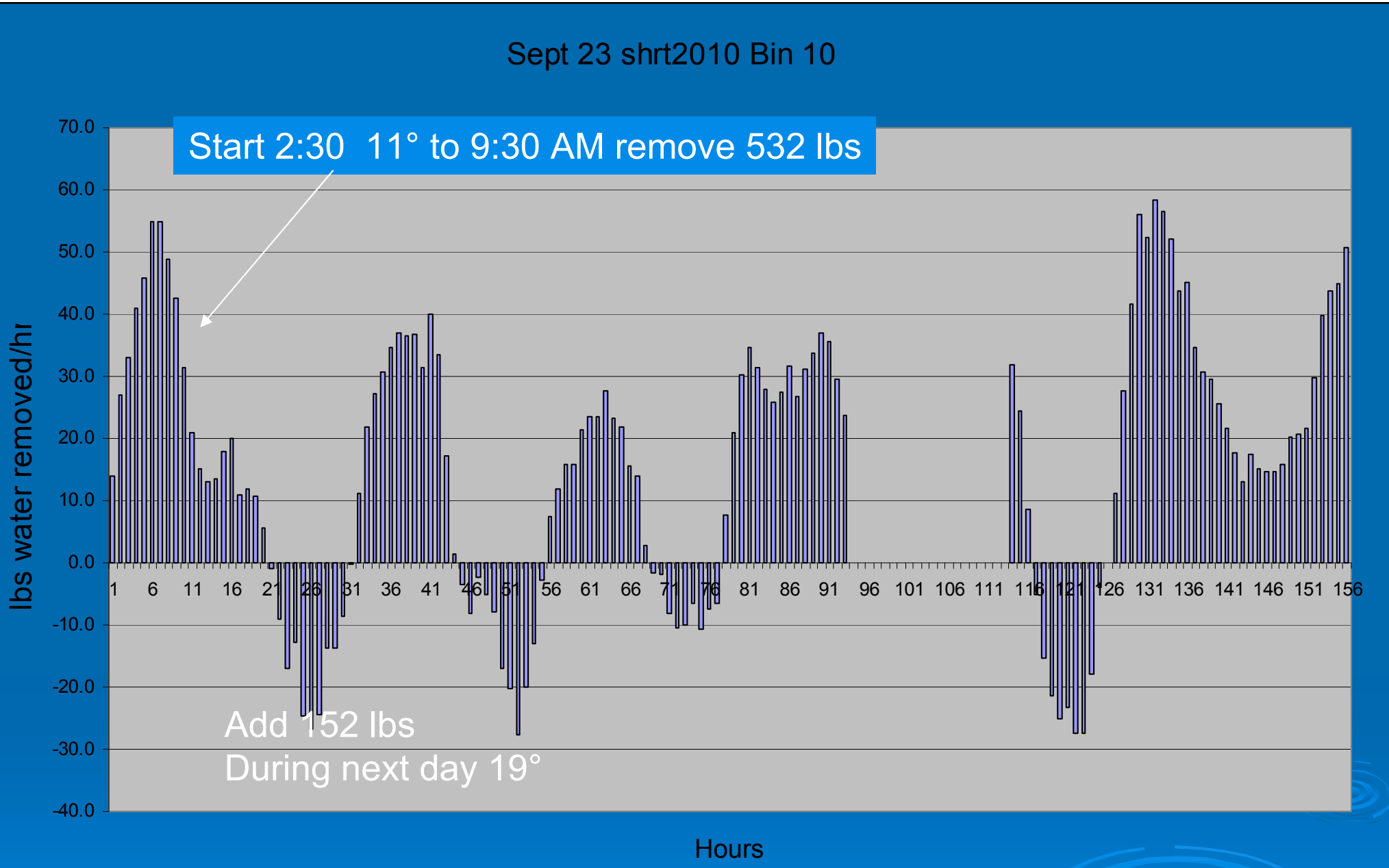
# Data stored hourly in Excel

| Date/Time | Low Temp | Mid Temp | High Temp | Air Leaving Temp | Air Leaving RH | CFM | Air Entering Temp | Air Entering RH |
|---|---|---|---|---|---|---|---|---|
| Date : Time | Low °C | Mid C | High °C | Air °C | R.H | CFM | | |
| 6/10/2010 12:23 | 9.64 | 11.38 | 9.23 | 26.33 | 50.44 | 0 | | |
| 6/10/2010 13:23 | 9.54 | 11.3 | 9.14 | 17.06 | 60.22 | 3636 | | |
| 6/10/2010 14:23 | 13.57 | 11.1 | 8.64 | 13.62 | 73.19 | 3450 | | |
| 6/10/2010 15:23 | 17.3 | 12.71 | 7.94 | 12.66 | 73.94 | 3128 | | |
| 6/10/2010 16:23 | 19.14 | 15.03 | 7.43 | 11.68 | 75.13 | 3516 | | |
| 6/10/2010 17:23 | 19.89 | 16.92 | 7.34 | 10.62 | 76.94 | 3048 | | |
| 6/10/2010 18:23 | 20.16 | 17.97 | 8.4 | 9.53 | 79.31 | 2680 | | |
| 6/10/2010 19:23 | 19.92 | 18.27 | 10.09 | 8.66 | 81.19 | 2620 | | |
| 6/10/2010 20:23 | 18.67 | 18.2 | 11.74 | 8.34 | 83 | 2680 | | |
| 6/10/2010 21:23 | 16.41 | 17.55 | 12.8 | 8.61 | 85.63 | 2658 | | |
| 6/10/2010 22:23 | 15.16 | 16.78 | 13.01 | 9.8 | 88.5 | 2520 | | |
| 6/10/2010 23:23 | 14.39 | 16.02 | 13.01 | 11.06 | 90.69 | 2954 | | |
| 7/10/2010 0:23 | 13.91 | 15.44 | 12.47 | 11.85 | 91.19 | 2718 | | |
| 7/10/2010 1:23 | 13.62 | 14.96 | 11.88 | 12.13 | 90.94 | 2814 | | |
| 7/10/2010 2:23 | 13.05 | 14.58 | 11.27 | 12.13 | 90.31 | 2980 | | |
| 7/10/2010 3:23 | 12.56 | 14.2 | 10.78 | 11.77 | 89.63 | 2724 | | |
| 7/10/2010 4:23 | 11.79 | 13.81 | 10.32 | 11.29 | 88.88 | 2794 | | |
| 7/10/2010 5:23 | 11.38 | 13.33 | 9.94 | 10.8 | 88.25 | 2718 | | |
| 7/10/2010 6:23 | 11.2 | 12.95 | 9.63 | 10.41 | 87.5 | 2790 | | |
| 7/10/2010 7:23 | 11.27 | 12.76 | 9.23 | 10.12 | 87.06 | 2904 | | |
| 7/10/2010 8:23 | 11.55 | 12.75 | 8.94 | 11.26 | 80.13 | 2774 | | |
| 7/10/2010 9:23 | 12.53 | 12.75 | 8.64 | 11.95 | 75.19 | 2498 | | |
| 7/10/2010 10:23 | 14.81 | 13.3 | 8.54 | 12.36 | 72.5 | 2436 | | |
| 7/10/2010 11:23 | 17.02 | 14.72 | 8.45 | 12.36 | 70.63 | 2454 | | |
| 7/10/2010 12:23 | 18.56 | 16.45 | 8.51 | 12.27 | 70.5 | 3304 | | |
| 7/10/2010 13:23 | 20.06 | 18.05 | 9.2 | 12.16 | 70.31 | 2304 | | |
| 7/10/2010 14:23 | 21.31 | 19.31 | 10.28 | 12.07 | 70.63 | 2766 | | |
| 7/10/2010 15:23 | 22.25 | 20.44 | 11.74 | 11.88 | 73.06 | 2390 | | |
| 7/10/2010 16:23 | 22.95 | 21.11 | 13.28 | 11.69 | 75.88 | 2180 | | |

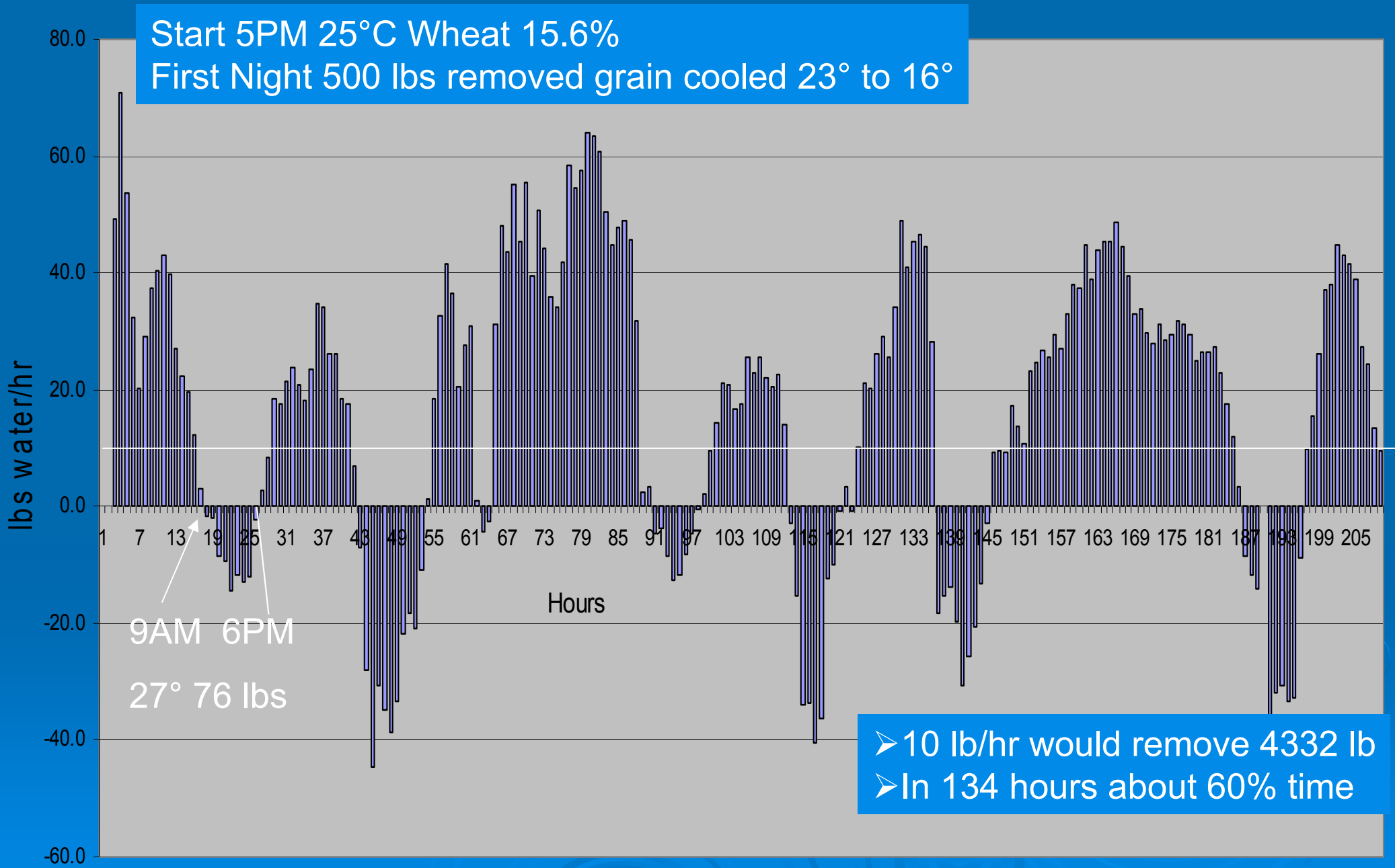
# Pea Bin 10 2009



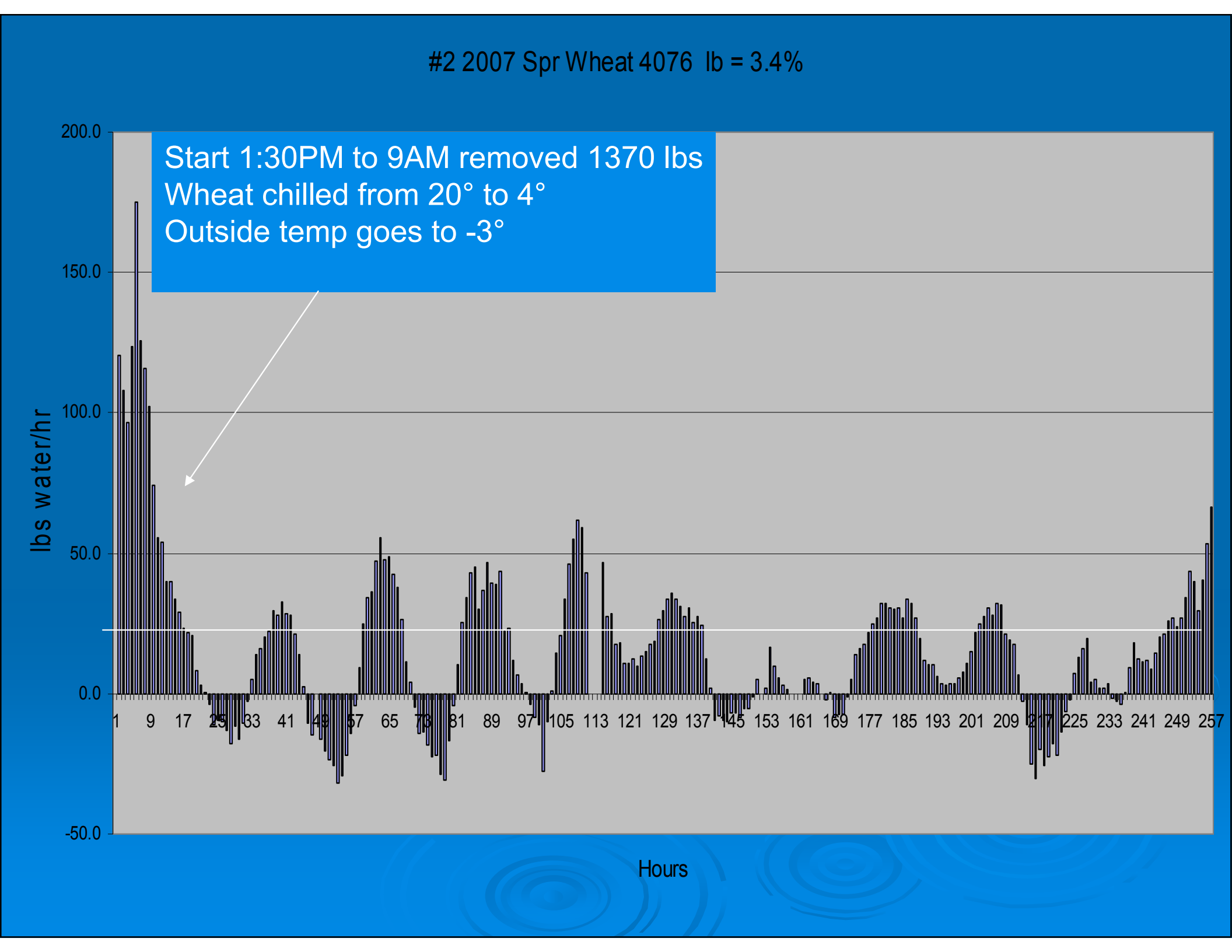

Bin 10 2011
200
150
100
50
0
-50
lbs water
1
16
31
46
61
76
91
106
121
136
151
166
181
196
211
226
241
256
271
286
301
316
331
346
361
376
hours

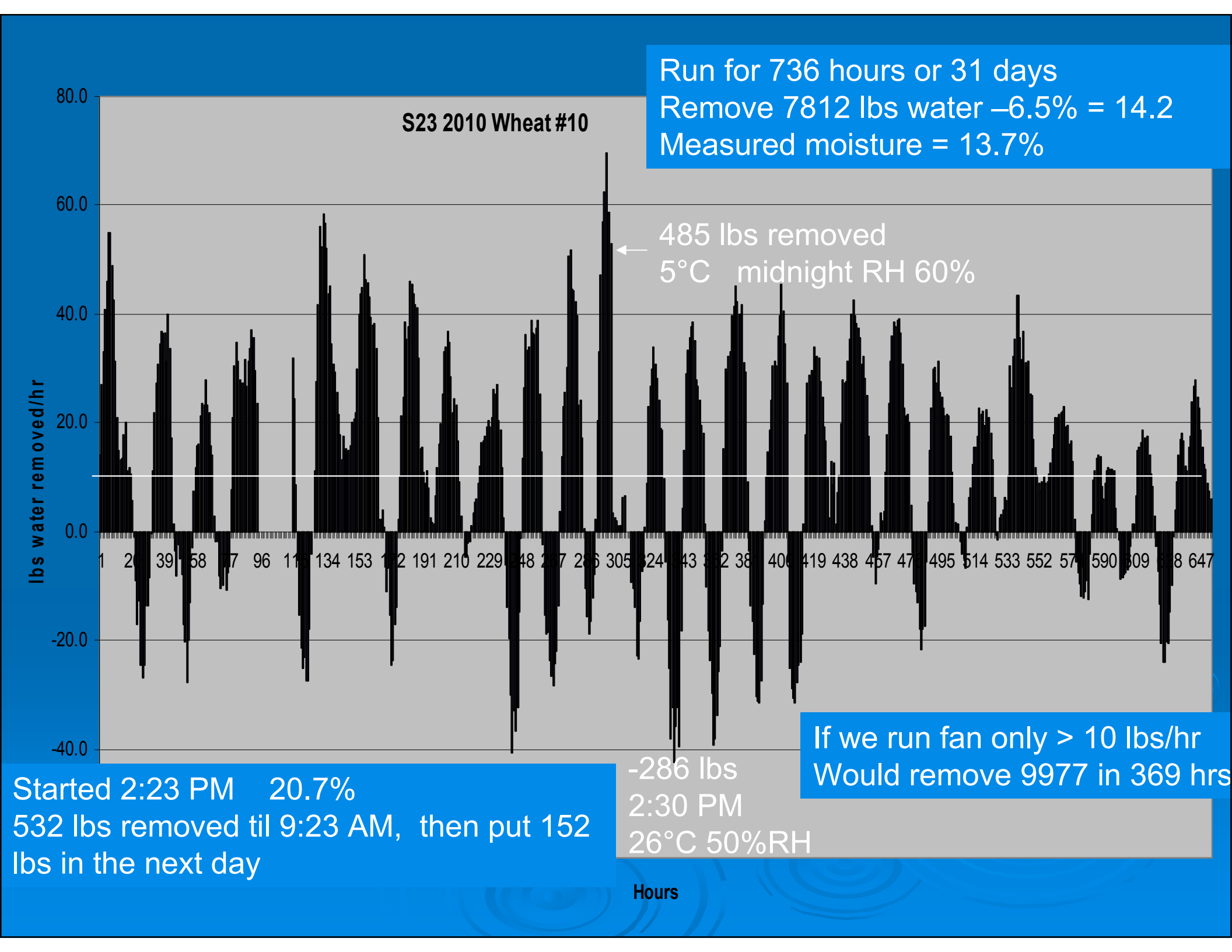

Sept 23 shrt2010 Bin 10
Start 2:30 11° to 9:30 AM remove 532 lbs
lbs water removed/hr
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141 146 151 156
Add 152 lbs
During next day 19°
Hours

# #1 3453 lbs 2.86% 2007 wheat

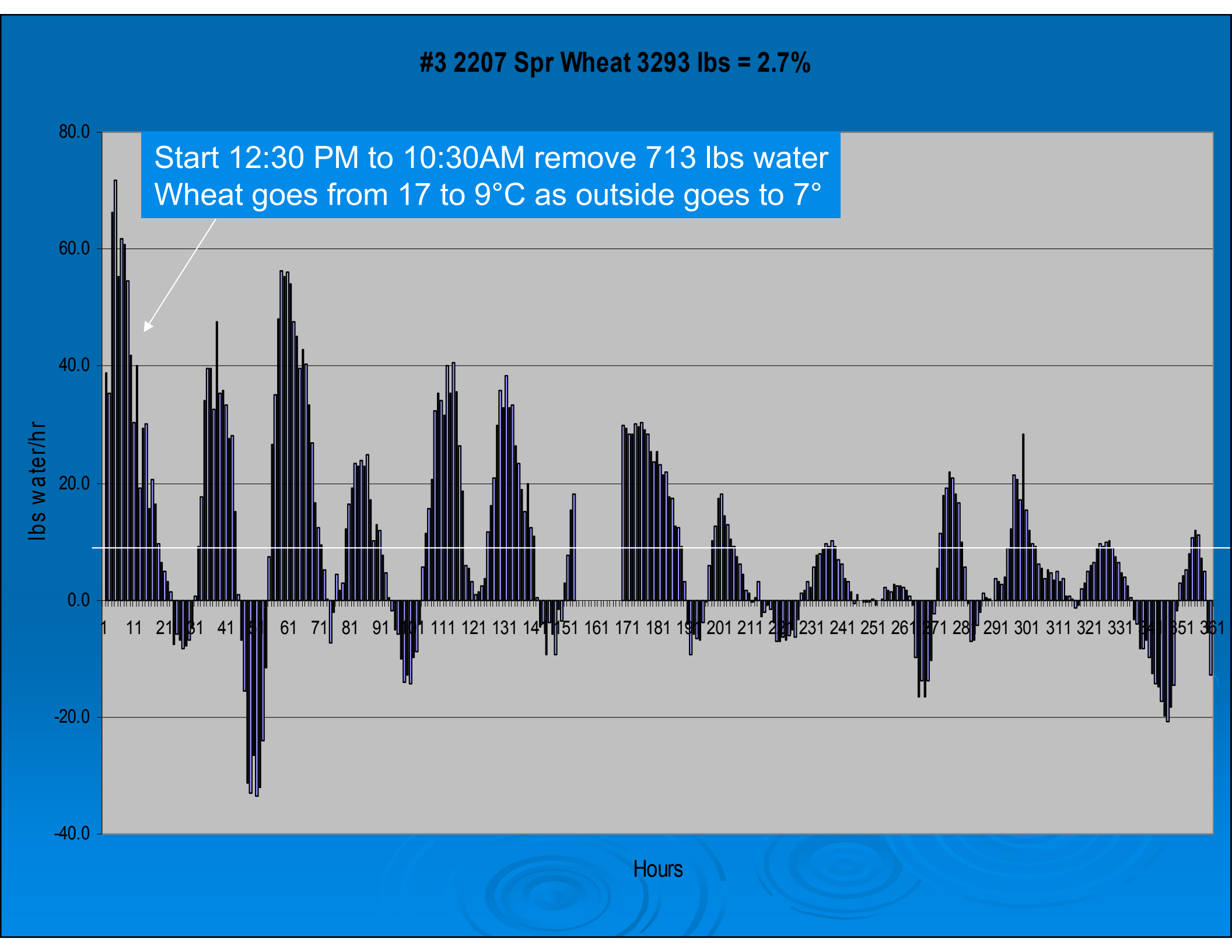


# #2 2007 Spr Wheat 4076 lb = 3.4%

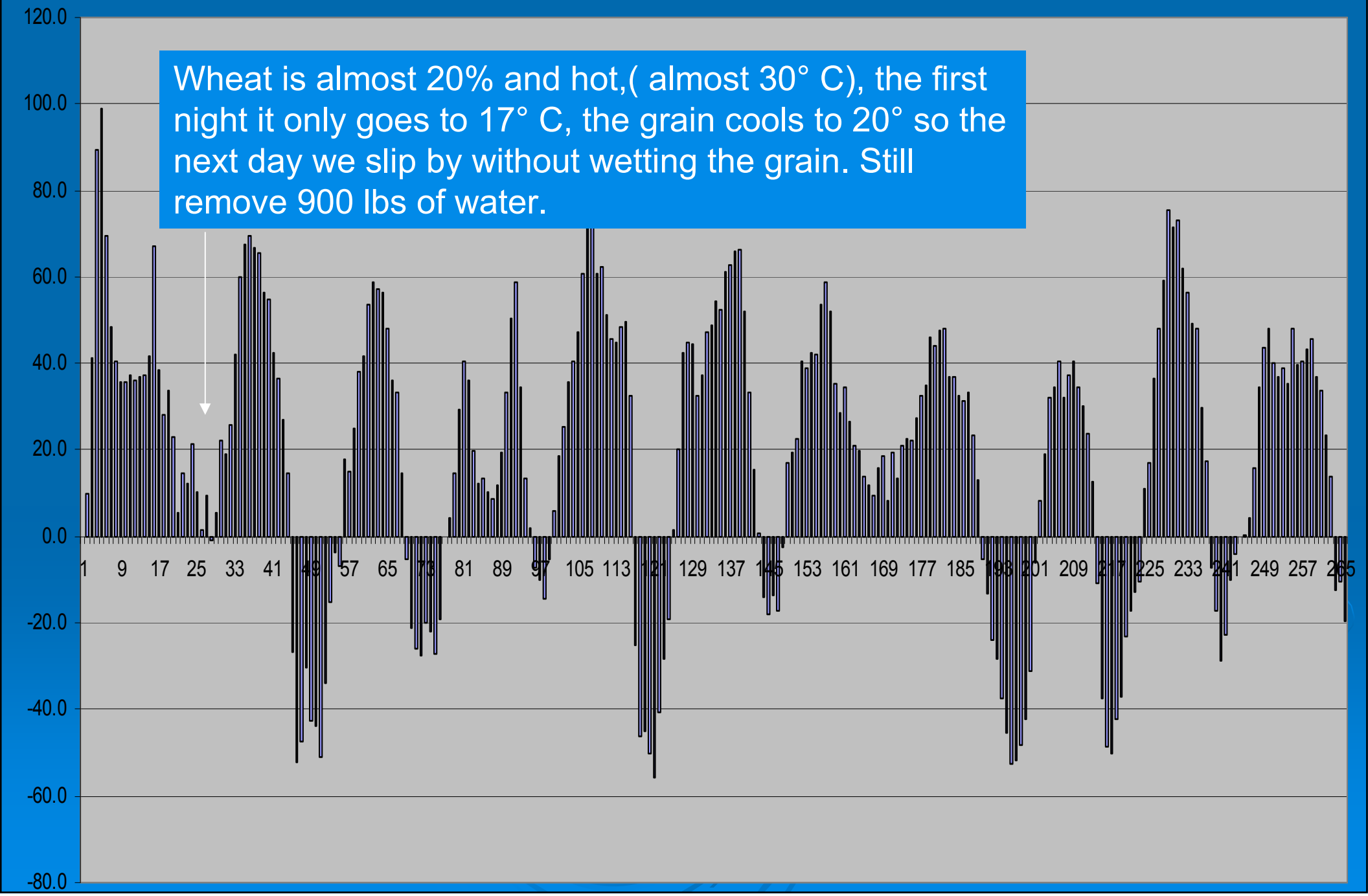



Run for 736 hours or 31 days
Remove 7812 lbs water –6.5% = 14.2
Measured moisture = 13.7%
S23 2010 Wheat #10
485 lbs removed
5°C midnight RH 60%
80.0
60.0
40.0
20.0
0.0
-20.0
-40.0
lbs water removed/hr
1 20 39 58 77 96 115 134 153 172 191 210 229 248 267 286 305 324 343 362 381 400 419 438 457 476 495 514 533 552 571 590 609 628 647
-286 lbs
2:30 PM
26°C 50%RH
If we run fan only > 10 lbs/hr
Would remove 9977 in 369 hrs
Started 2:23 PM 20.7%
532 lbs removed til 9:23 AM, then put 152 lbs in the next day
Hours

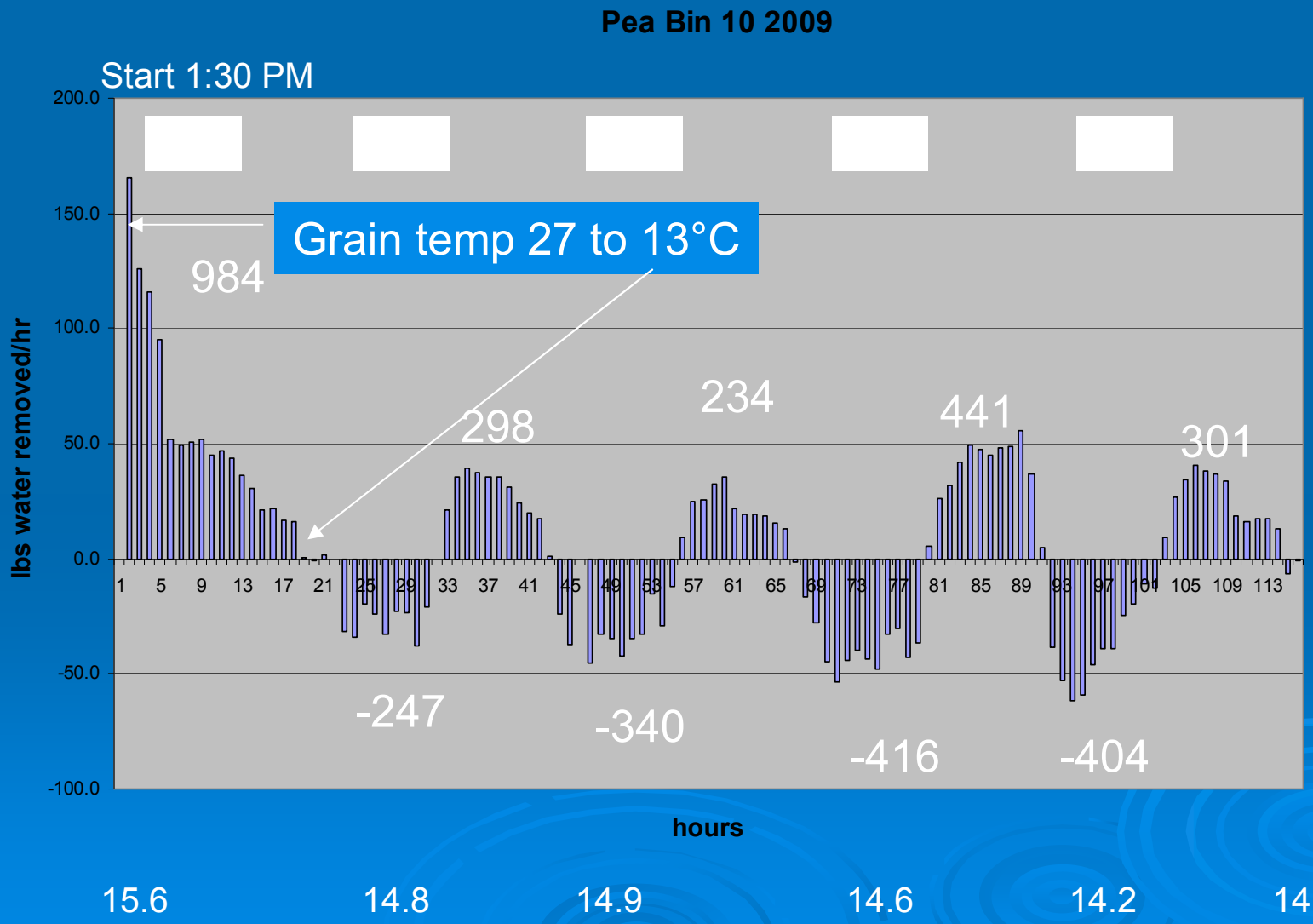
# #3 2207 Spr Wheat 3293 lbs = 2.7%



# Wheat Bin 9 2009

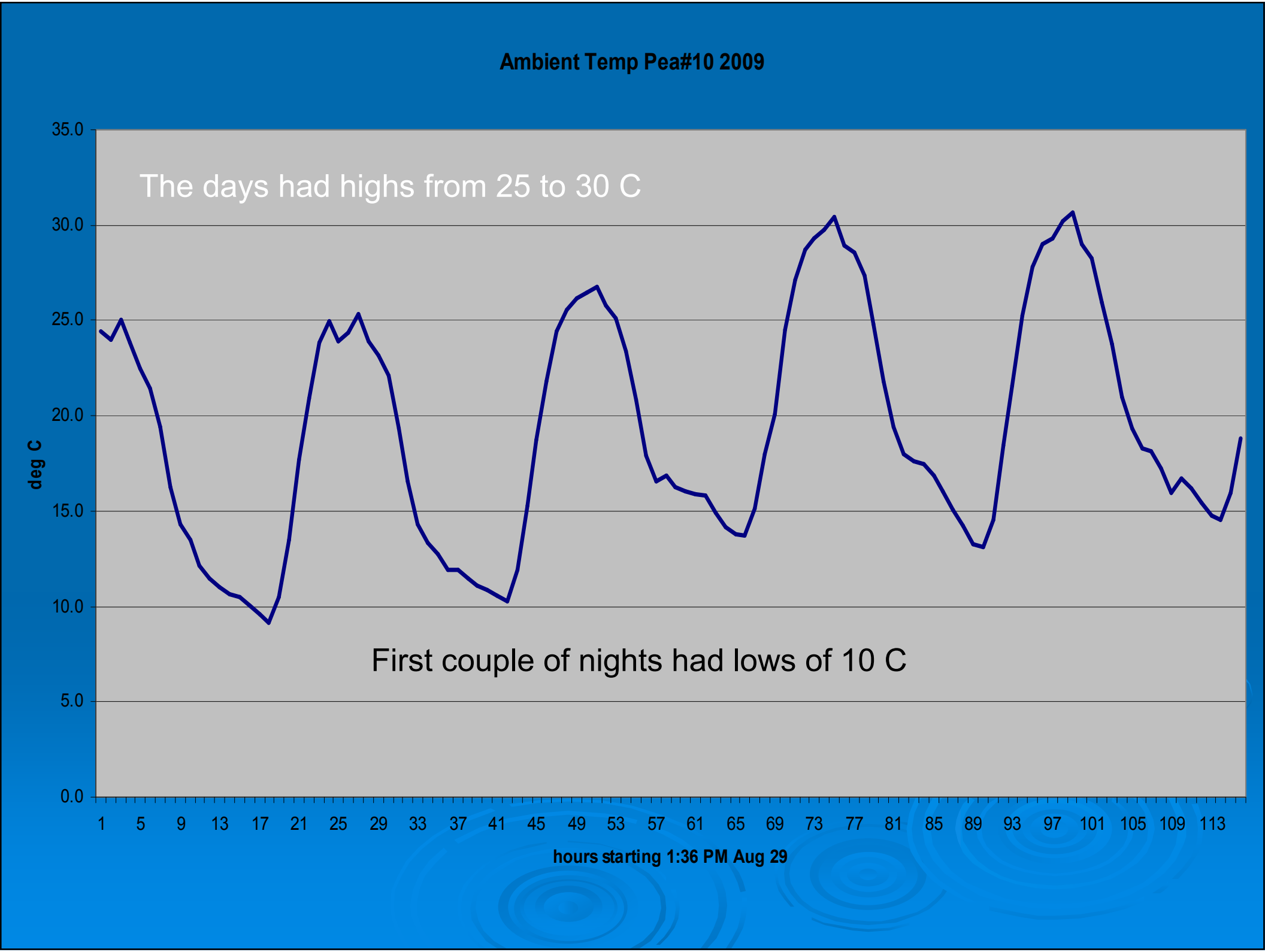


Start 1:30 PM – 8:00 AM = 984 lbs removed
9:00 AM – 9:00 PM = -247 lbs (added)
9 – 9 night = 298 removed
9 – 9 day = -340 (added)



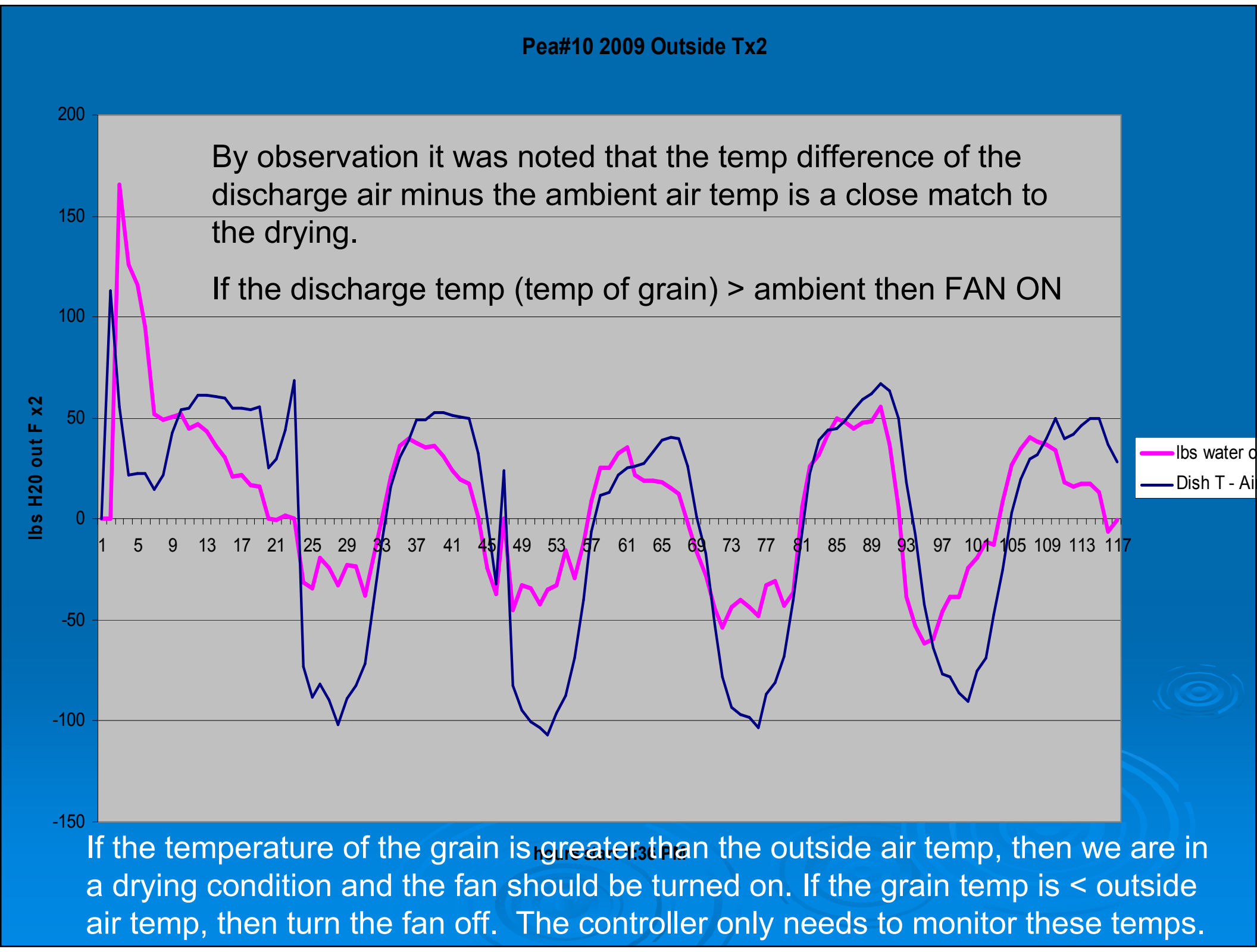

Net 851 lbs

15.6 14.8 14.9 14.6 14.2 14.2

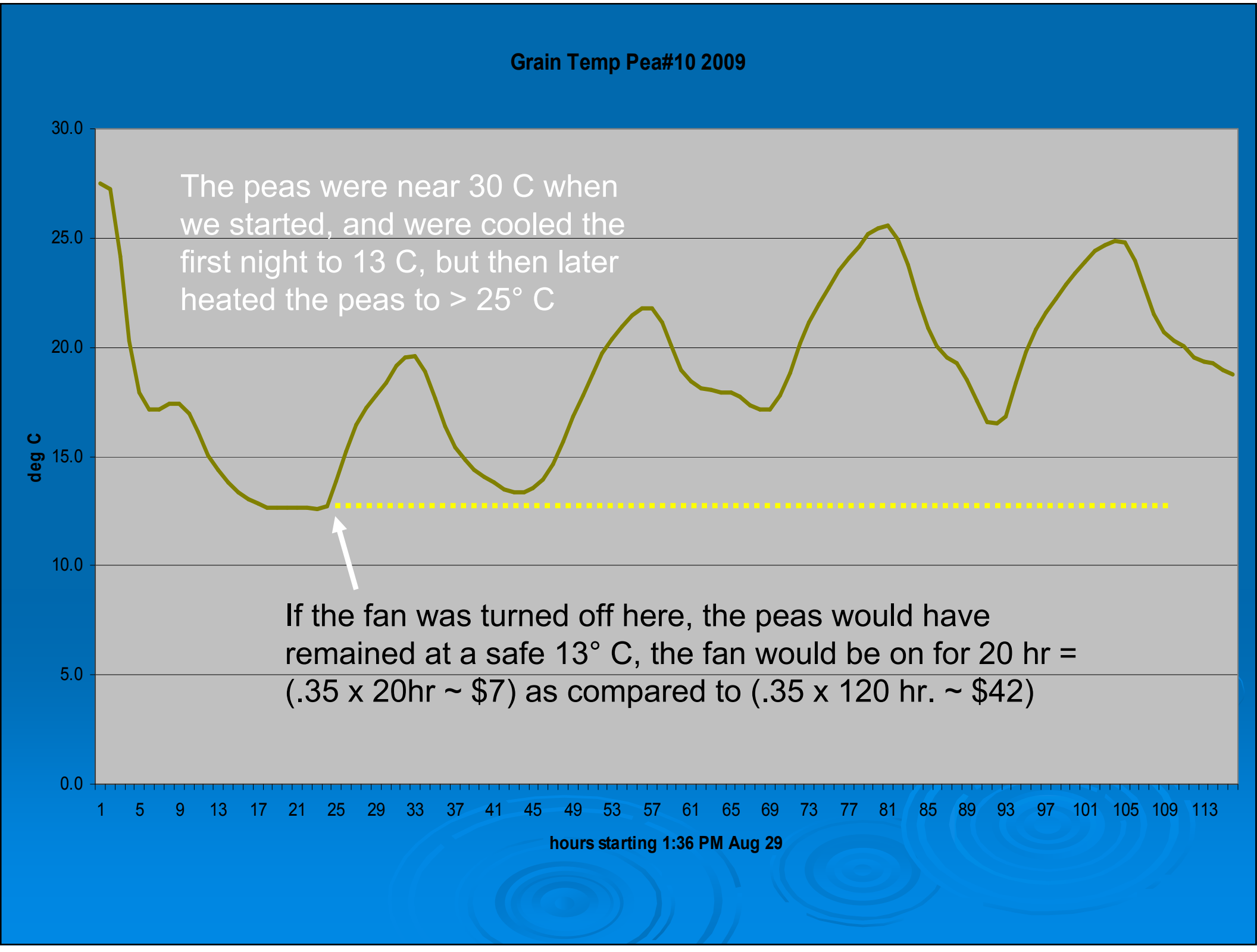

Ambient Temp Pea#10 2009
The days had highs from 25 to 30 C
First couple of nights had lows of 10 C
deg C
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101 105 109 113
hours starting 1:36 PM Aug 29

# What's going on here??

- First day, warm air hits the warm grain and plenty of drying takes place.
- First night, cool dry air hits the warm grain. The air is warmed by the grain, lowering its RH – so it can hold more water, and so it does by drying the grain.
- The next day, the warm moist air hits the cool grain, cooling the air. Moisture is released into the grain.




If the temperature of the grain is greater than the outside air temp, then we are in a drying condition and the fan should be turned on. If the grain temp is < outside air temp, then turn the fan off. The controller only needs to monitor these temps.


Grain Temp Pea#10 2009
30.0
25.0
20.0
15.0
10.0
5.0
0.0
deg C
The peas were near 30 C when we started, and were cooled the first night to 13 C, but then later heated the peas to > 25° C
If the fan was turned off here, the peas would have remained at a safe 13° C, the fan would be on for 20 hr = (.35 x 20hr ~ $7) as compared to (.35 x 120 hr. ~ $42)
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101 105 109 113
hours starting 1:36 PM Aug 29

# Recommendations

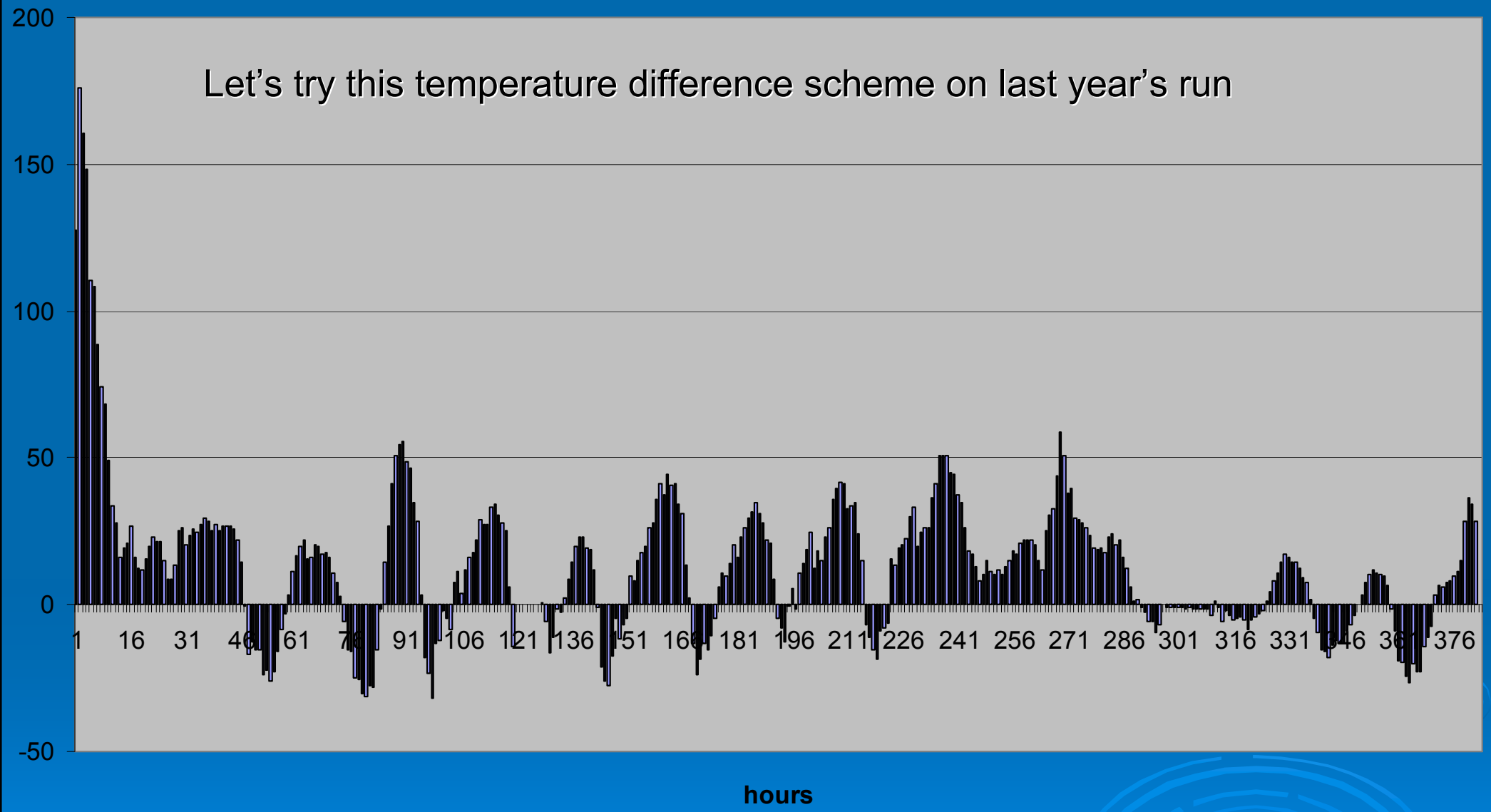
- GOOD – if you insist on running the fan continuously, when you do turn it off, do so in the early morning (when it is cold).
- BETTER – turn the fan off during the day and on at night.  (Yard light rule)
- BEST – a controller:
  - If ambient air temp < grain temp → FAN ON
  - If ambient air temp > grain temp → FAN OFF

# It Works!

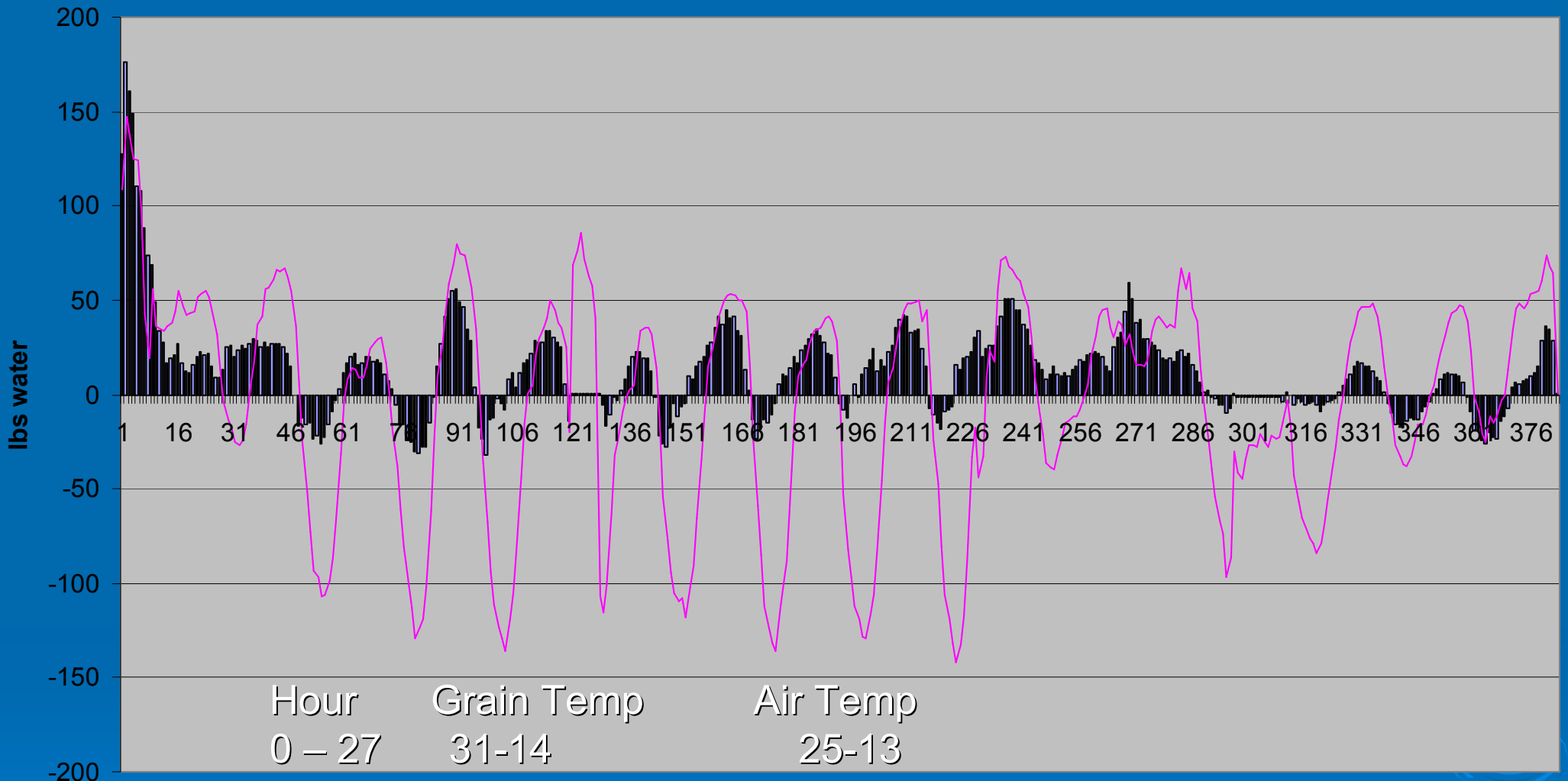
- Chad Skinner has tried this with side by side trials and found the on-night/off-day was as effective as the continuous-fan-on.
- Lentils 18% to 14% in 5 days (3hp 2000 & 3300)
- Wheat 17% to 13% in 7 days (7.5hp 5000bu)
- Canola

Conclusion: Only need to run the fan half the time and your grain will be **cooler** and **safer**

# Bin 10 2011


Let’s try this temperature difference scheme on last year’s run
200
150
100
50
0
-50
1
16
31
46
61
91
106
121
136
151
166
181
196
211
226
241
256
271
286
301
316
331
376
hours

# Bin 10 2011




| Hour | Grain Temp | Air Temp |
|---|---|---|
| 0 – 27 | 31-14 | 25-13 |
| 36-48 | 14-9 | 13-8 |
| 259-289 | 12 -5 | 12-5 |
| 302-312 | 5.6-6 | 5- 5.49 |

Fan on for 81 hrs ($28) instead of 383 hrs ($134) and grain at 6° C

# Observations

- Cooling the grain also dries it.
- An enormous amount of water is removed the first day as the grain is cooled.
- The top remained at the same moisture content, until the ‘dry-front’ came up.
- Best drying takes place at night, while significant wetting occurs during hot days.
- Temp difference Grain – Air → Drying

# Conclusions

- Best drying conditions are when the air is cold and the grain is hot.
- Its not a race *to dry the grain before it spoils*, it is a race *to cool the grain before it spoils*.
- For the best grain storage, keep the grain as cold as possible. < spoilage, < OTA, < mold
- Only need to run the fan half the time (night), 50% saving in electricity.
- Best strategy is to run the fan only if we are drying the grain.

# Yard Light Rule

On at night
You are bright
On upon day
You will pay

And that's the lesson of the day!

Questions?

Comments?