Grain Aeration – The Fundamentals

The Alternate Facts about Aerating Grain
IHARF Soil and Crop Management Seminar

Ron Palmer P.Eng. Ph.D.

ron.palmer@uregina.ca

grain-aeration.com

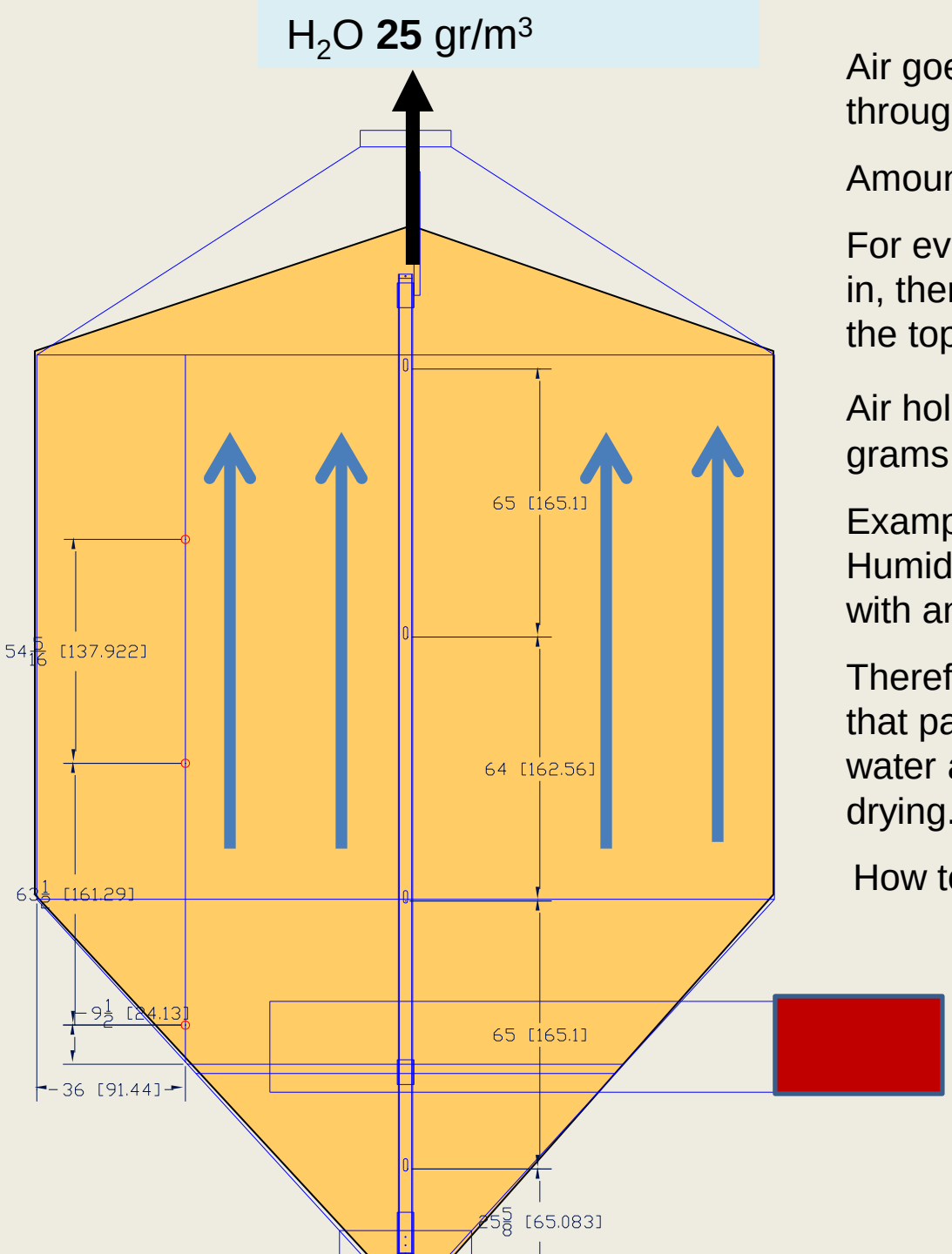
Indian Head Agricultural Research Foundation

Western Grain Research Foundation

McKenna Auditorium,

Weyburn, Sask.

Weds, Feb 1, 2017 2:45 PM



Air goes in through the fan, passes through the grain, and exits the bin

Amount of Air In = Amount of Air Out

For every cubic meter of air that goes in, there is a cubic meter that exits at the top.

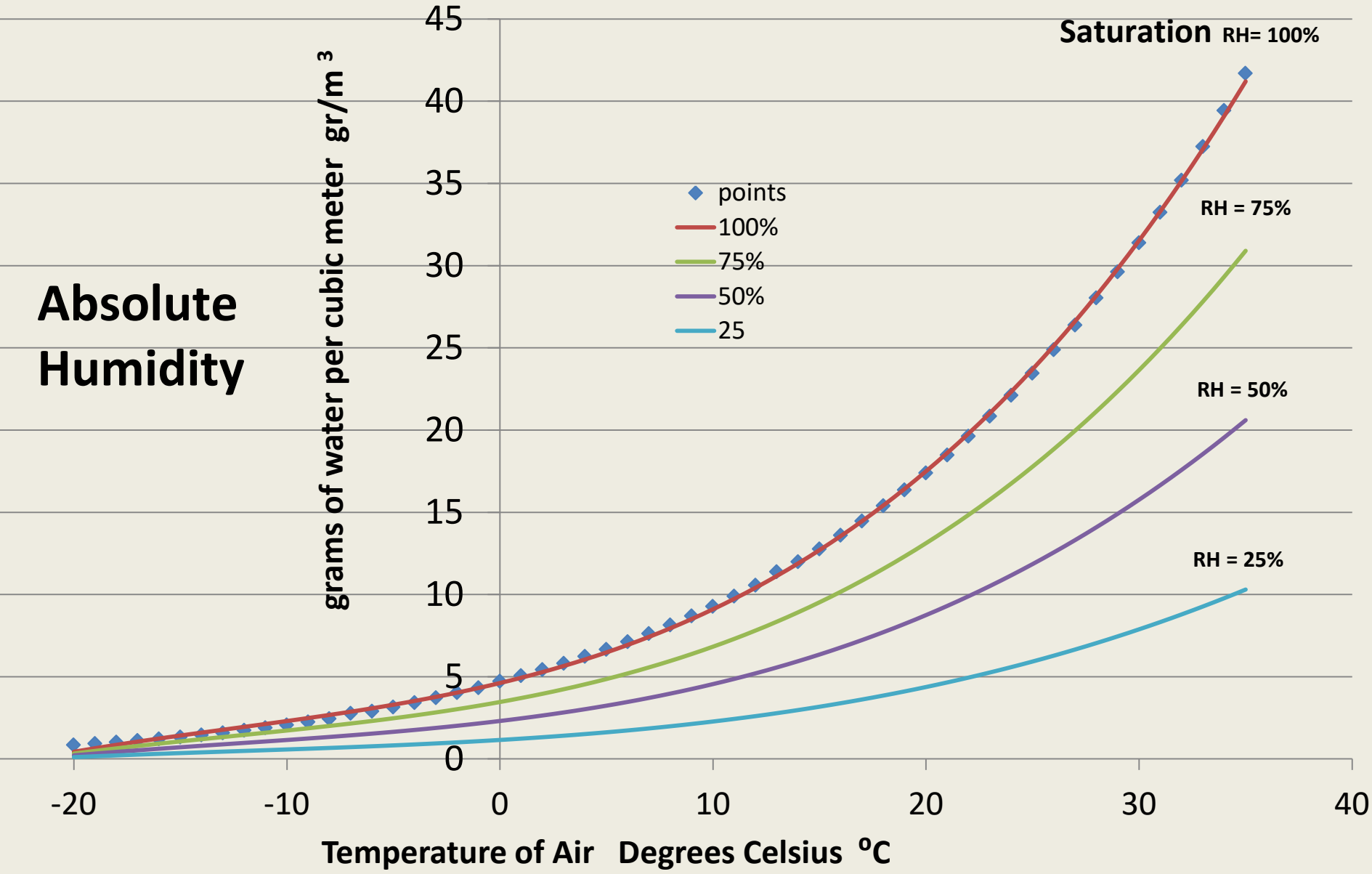
Air holds water**, Absolute Humidity** grams per cubic meter (m^3)

Example: Air entering has an Absolute Humidity of **20** gr/m^3 and exits the bin with an Absolute Humidity of **25** gr/m^3

Therefore for every cubic meter of air that passes through the bin, **5** grams of water are being removed. We are drying.

How to determine **Absolute Humidity**?

Water in the Air



Get Absolute Humidity from T & RH

- Use the graph Temp-->RH--> AbsHum
- Use online calculator **planetcalc.com/2167/**
  - **R**elative **H**umidity % 74
  - Air **T**emperature ^{o} C 32
  - it calculates the absolute humidity kg/m^3 .025
- Use equation:

Absolute Humidity = Saturation Humidity x RH

$$=(0.000289\ \mathbf{T}^3 + 0.010873\ \mathbf{T}^2 + 0.311043\mathbf{T} + 4.617135) \times \mathbf{RH}$$

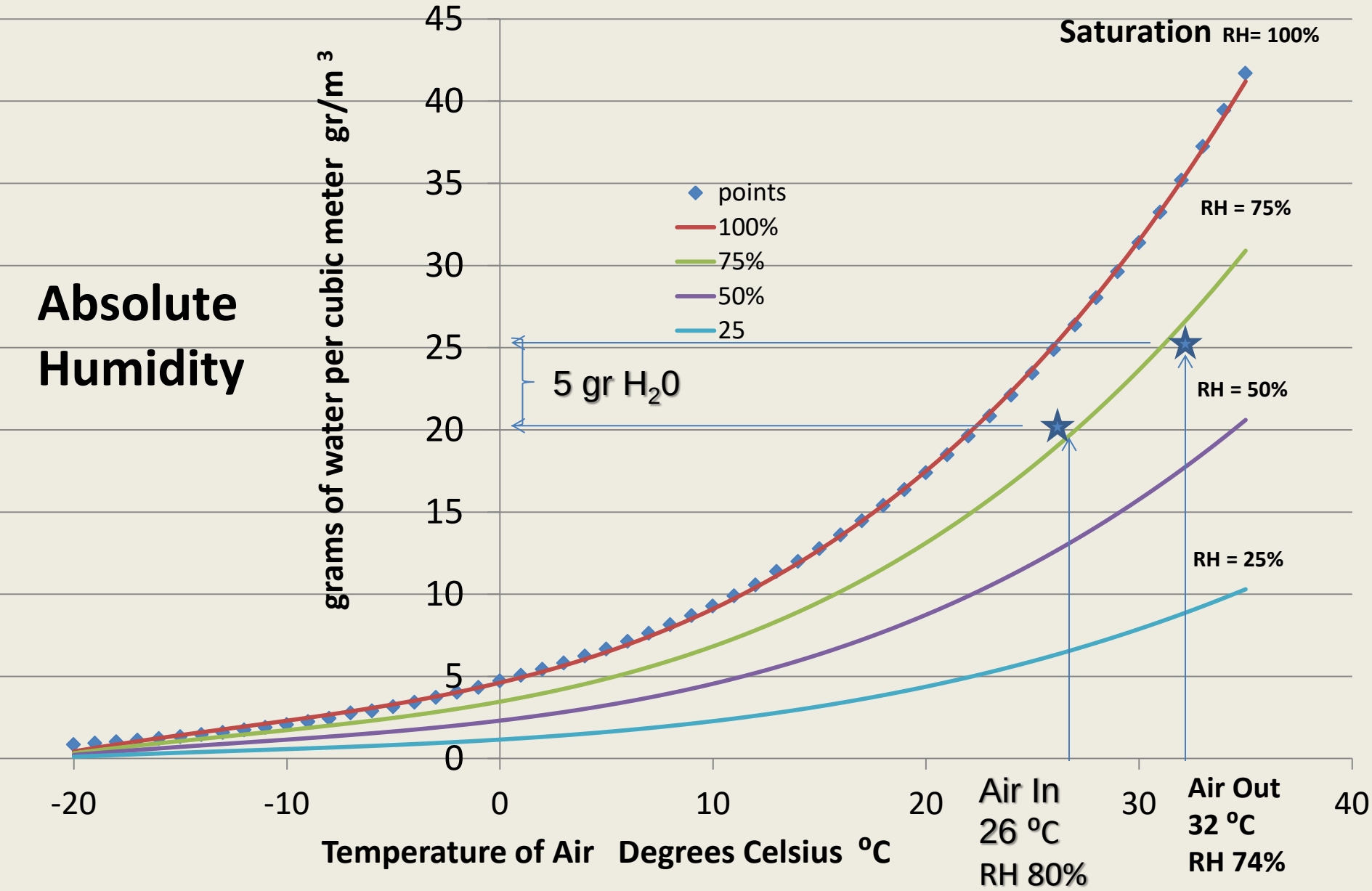
Absolute Humidity, a function of Temperture & Relative Humidity

Example

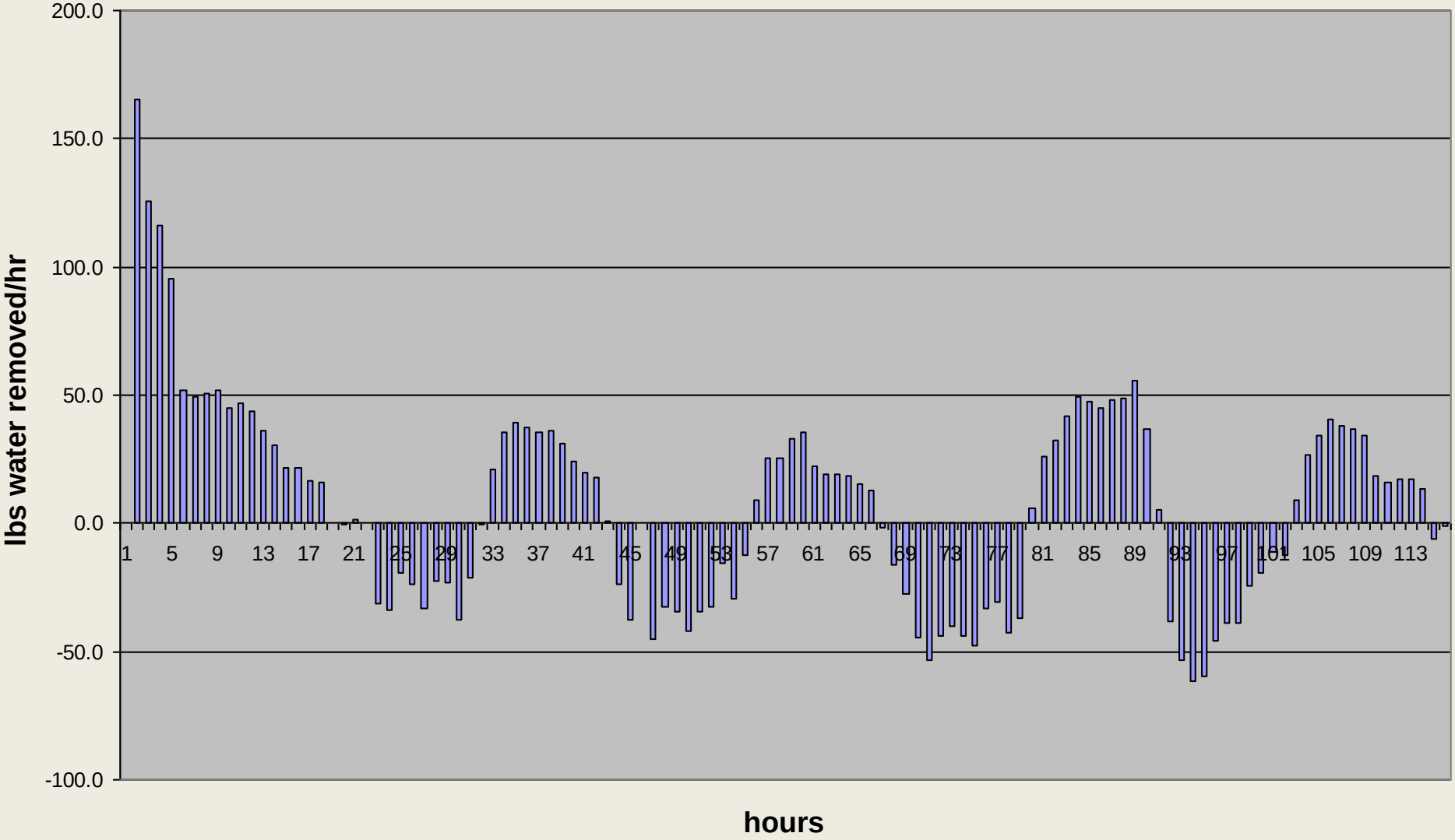
- Air In: 26 ^{o}C, RH 80% → Abs Hum 20 gr/m^3
- Out Air: 32 ^{o}C, RH 74% → Abs Hum 25 gr/m^3
- For every cubic meter that flows through the bin, five grams of water is removed.
- Let's say our CFM is 3000. There are 35.31 cubic feet in a cubic meter, so 85 m^3/min or 5098 m^3/hr x 5 gr/m^3 = 25,488 gr/hr or 25.488 kg/hr or

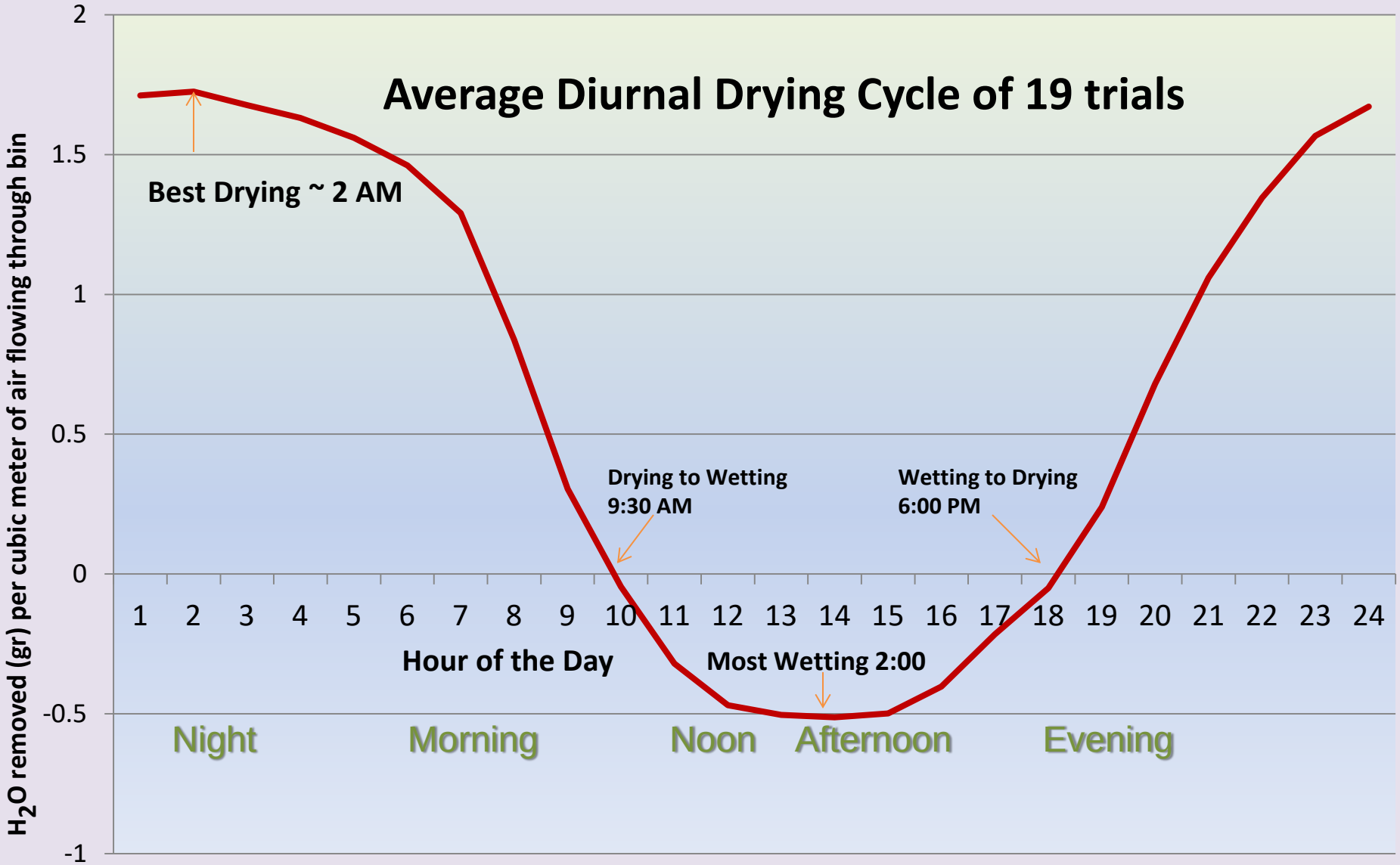
  56.17 lbs of water removed every hour.

Water in the Air



Pea Bin 10 2009




Average Diurnal Drying Cycle of 19 trials
Best Drying ~ 2 AM
Drying to Wetting
9:30 AM
Wetting to Drying
6:00 PM
Most Wetting 2:00
Hour of the Day
Night
Morning
Noon
Afternoon
Evening
H_2O removed (gr) per cubic meter of air flowing through bin
2
1.5
1
0.5
0
-0.5
-1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

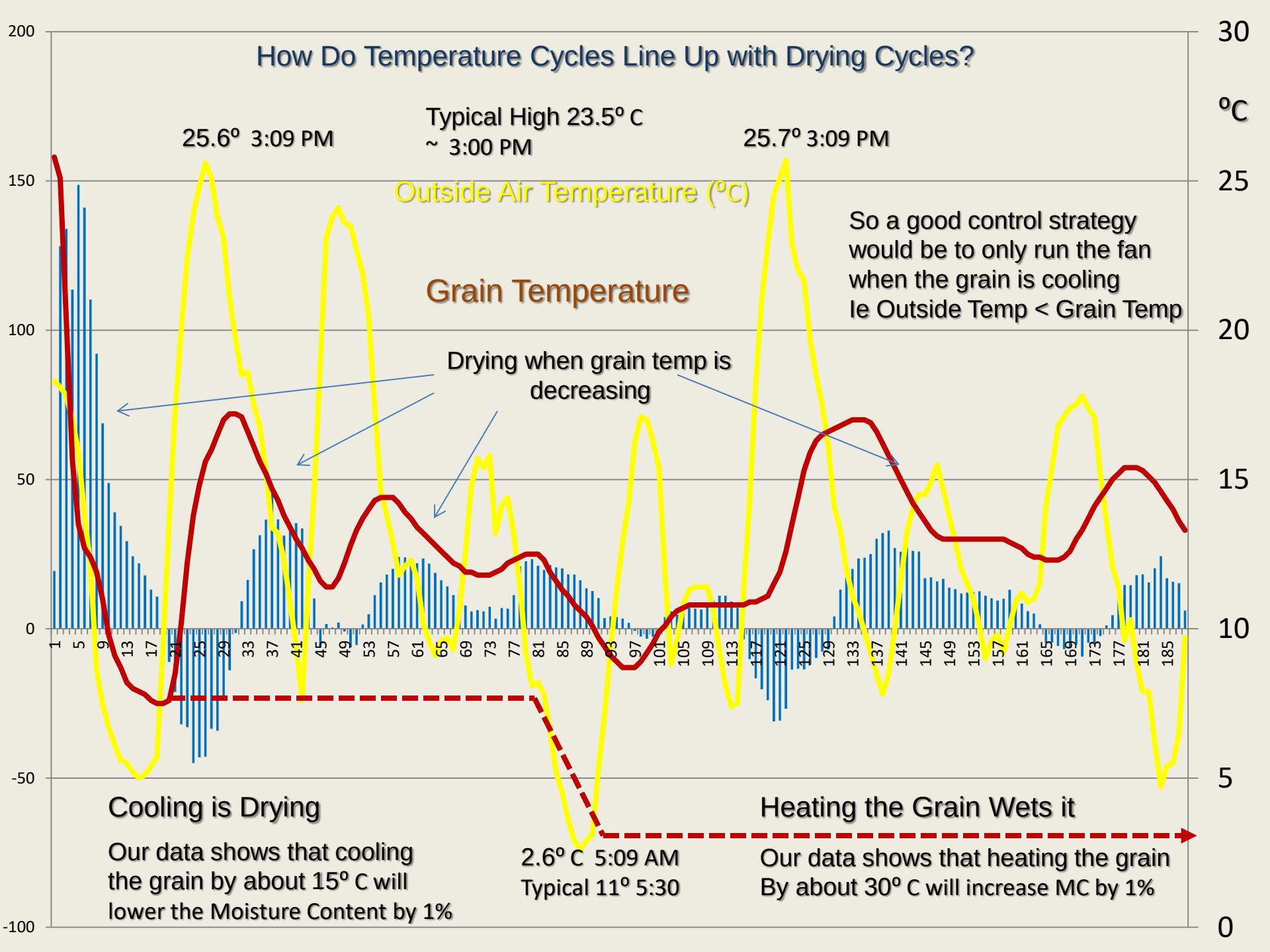
Night Drying Recommendation

- Yard Light Rule (2010):

On at night, you are bright

On during the day, you will pay.

- Requires no sensors, or calculations, or knowledge of grain type, temp, RH etc.
- Turn off at 9 AM
- Does not account for MC, air T or RH, nor grain T and therefore may not be the best.


How Do Temperature Cycles Line Up with Drying Cycles?
Typical High 23.5º C
~ 3:00 PM
25.6º 3:09 PM
25.7º 3:09 PM
Outside Air Temperature (ºC)
Grain Temperature
So a good control strategy would be to only run the fan when the grain is cooling
Ie Outside Temp < Grain Temp
Drying when grain temp is decreasing
Cooling is Drying
Our data shows that cooling the grain by about 15º C will lower the Moisture Content by 1%
2.6º C 5:09 AM
Typical 11º 5:30
Heating the Grain Wets it
Our data shows that heating the grain By about 30º C will increase MC by 1%
ºC
200
150
100
50
0
-50
-100
30
25
20
15
10
5
0

Cooling is Drying

- Turn the Fan on if:

(Air Temperature + Offset) < Grain Temperature

The MC of the grain, and outside air RH are not accounted for, so again we could question: Is this the best? Can we also account for the MC and RH?

This strategy requires a minimum of sensors – only the temperature of the grain.

May want to further restrict – on if RH < 85%

Temp and RH sensor

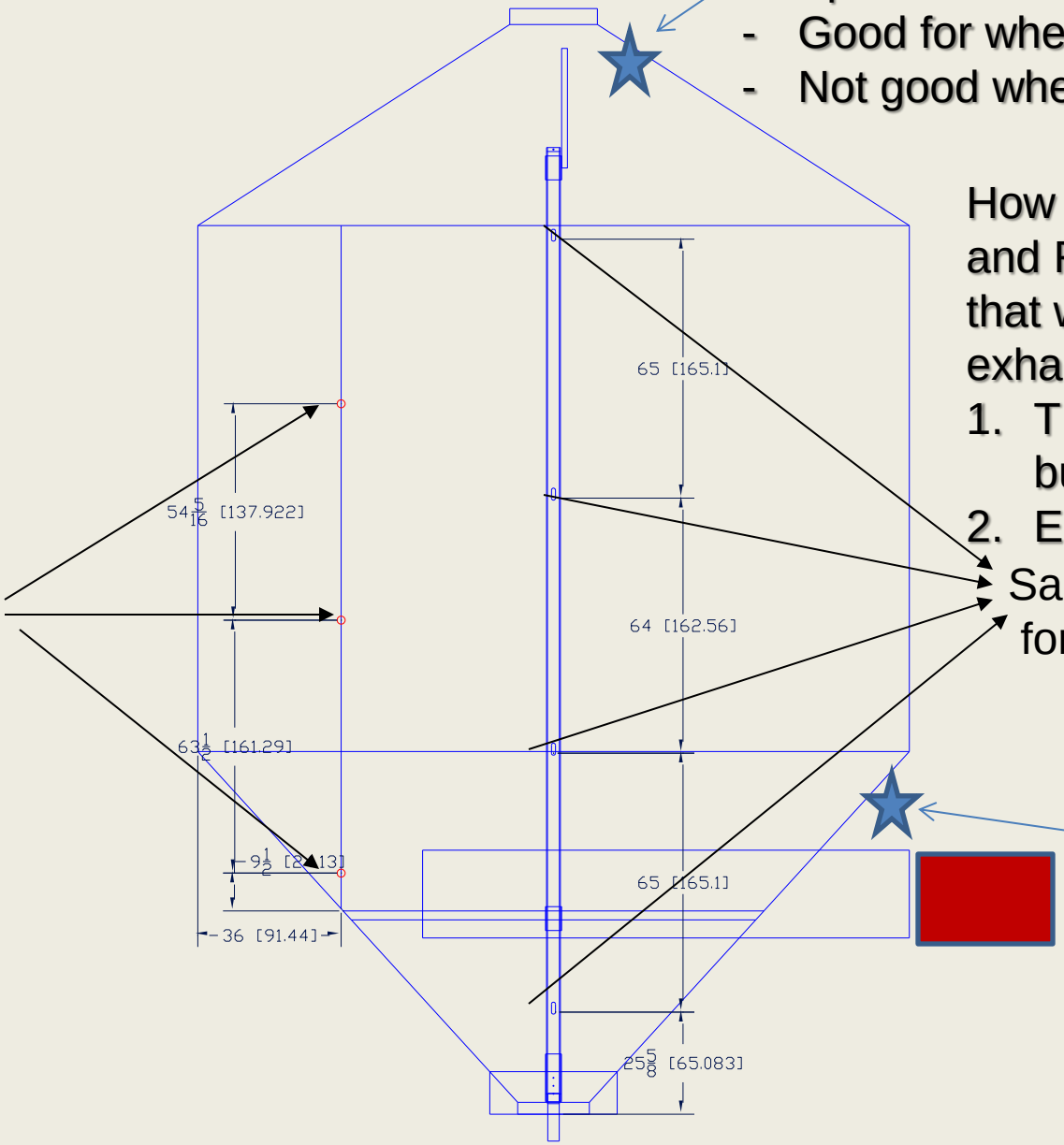
- Good for when fan is running
- Not good when fan stopped

How do we get the T and RH of the air that will be exhausted?

1. T & RH sensor buried in grain
2. EMC

Sampling ports for Grain Moisture

Temperature Probes



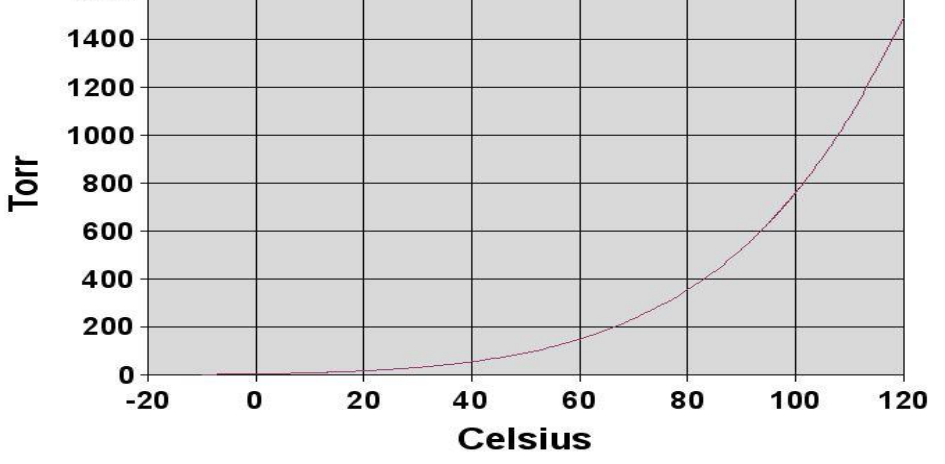
Easy to get T and RH of the outside air.

Moisture Cables provide T & RH

- If you have so called moisture cables, they will have temperature and RH sensors located every 4 feet.
- When the fan is running we get the T & RH with a sensor located where the air exits the bin.
- When the fan is stopped, use a sensor buried in the top layer of grain. This is what the exhaust air will be when the fan starts.

If you don’t have moisture cables, but only know the temperature of the grain by probing or temp cables

- The temperature of the exhaust air will be the same as the grain temperature; but where will we get the RH of the exhaust air?
- The exhaust air will be the air that is surrounding the grain right now. We have the temperature but we need the RH.
- We will use Equilibrium Moisture Content (EMC) equations to get the RH.



Vapour Pressure

Air surrounding kernel

Grain kernel

Water trying to get in

= Vapour Pressure Air

- temperature
- relative humidity

Water trying to get out

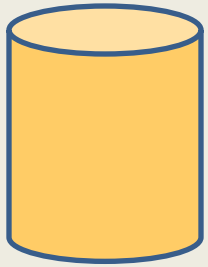
= Vapour Pressure Grain

- % moisture content
- temperature
- type & condition of grain

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

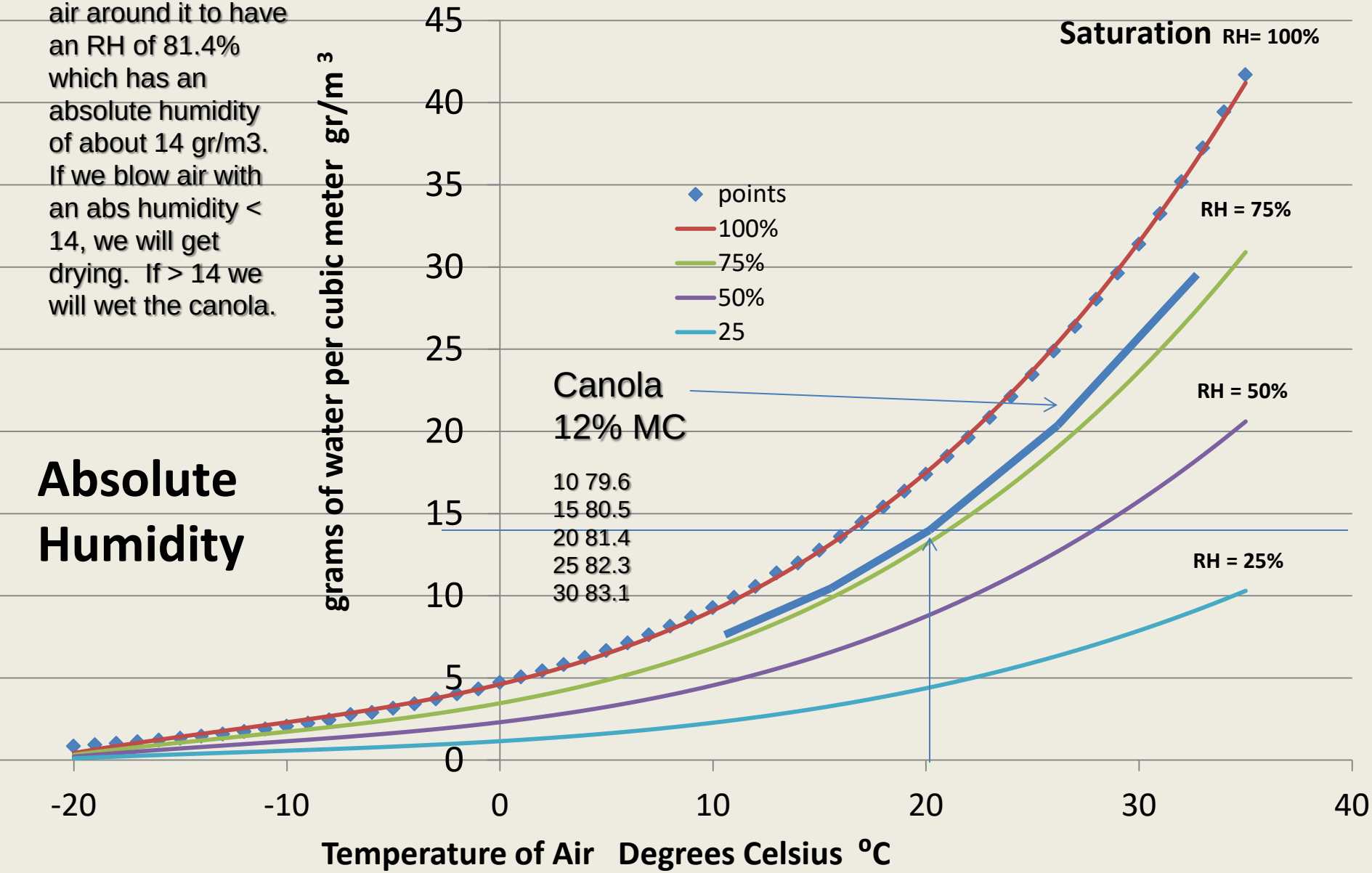
EMC Equilibrium Moisture Content



- Grain put in a sealed container at a given **MC** and **T**
- Wait until equilibrium reached (grain and air at same **T**)
- Moisture Content (**MC**) **←→** Relative Humidity (**RH**)
- For each grain, graph **MC** vs. **RH** then find EMC equation
- Many have done this with slightly different equations
- Henderson, Chung, Pfost
- If you have a bin (considered sealed) that has been sitting with grain in it for awhile (equalized) and you know the **T** and **MC** you can plug this into an **EMC** equation to get **RH** = **{**… **MC** …. **T }** but only if the air is the same **T** as the grain
- The operative word is **equilibrium**, the grain and air must be at the same **T**. Using this **T** and **MC** of grain, plug into EMC to get **RH**. Using this **RH** and grain **T** → **Absol Humid**

Water in the Air

Consider Canola @ 12 % MC and 20 C It will equalize the air around it to have an RH of 81.4% which has an absolute humidity of about 14 gr/m3. If we blow air with an abs humidity < 14, we will get drying. If > 14 we will wet the canola.



How to Use EMC to determine drying conditions

1. Find the RH of the air inside the bin using EMC eq. for grain at T and MC
2. Calculate the saturation absolute humidity for air that is the same T as the grain
3. Find the absolute humidity of the air inside the bin by multiplying 1. x 2.
4. Calculate the saturation absolute humidity of the outside air at its T
5. Determine the threshold RH by dividing 3. by 4. If the outside air has a RH that is less than the threshold RH, then we have drying conditions.
6. Fortunately all this math is done with the grain drying calculator. Simply enter the MC of the grain, its T and the outside temperature. The calculator will calculate the threshold RH for a number of grains using the steps above. Find the grain in question, and its threshold RH. If the outside air has an RH that is lower than this then we have air that will dry your grain.

The Grain Drying Calculator

- Input MC%, Grain Temp, Air Temp → RHthres
- **planetcalc.com/4959/**

Grain Moisture Content % 12

Grain Temperature ^{o} C 20

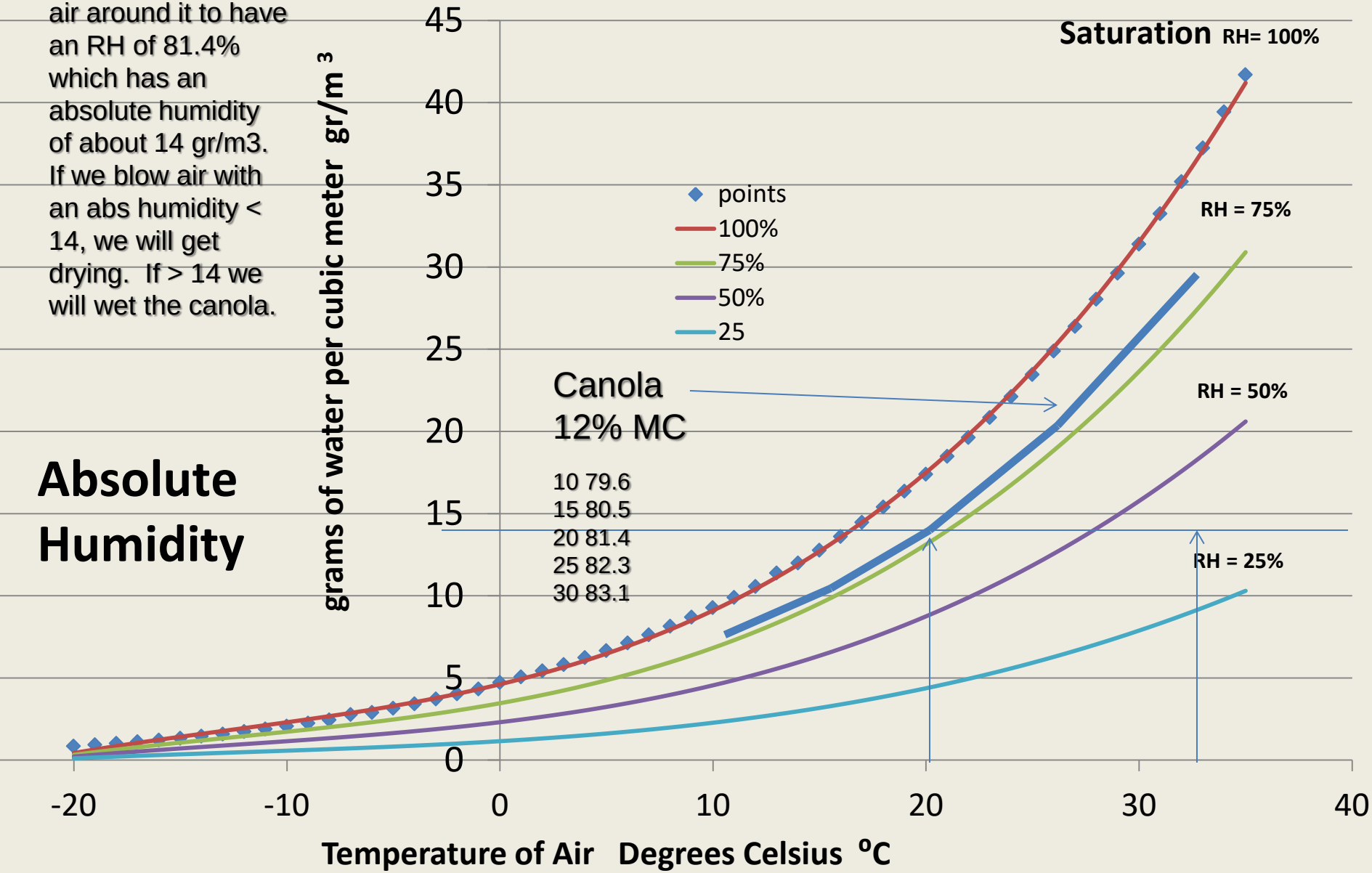
Air Temperature ^{o} C 32

Calculate

Grain	Threshold Relative Humidity
Xxx	xxx
Canola (Henderson)	41.5
Canola (Chung Pfost)	42.0

Water in the Air

Consider Canola @ 12 % MC and 20 C It will equalize the air around it to have an RH of 81.4% which has an absolute humidity of about 14 gr/m3. If we blow air with an abs humidity < 14, we will get drying. If > 14 we will wet the canola.



Objective

- To build a fan controller or strategy 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
    - ➢ Dries Grain to market-dry levels

Strategy

Only run the fan when ambient air conditions will result in the drying of the grain;

OR: only run the fan to make the grain as cold as possible?? Or as **SAFE** as possible ??

SAFE STORAGE TIME (days) CEREAL GRAINS $\log_{10}$ **(safe days)** = 6.2 – 0.3 **MC%** - .07 **°C** Fraser & Mu

germination reduced by 5%

14.5% @ 30°C = 38 safe days
14.5% @ 20°C = 128 safe days
14.5% @ 0°C = 1458 safe days

Grain Temp°C	**Grain Moisture Content**										
	14%	**15%**	**16%**	**17%**	**18%**	**19%**	**20%**	**21%**	**22%**	**23%**	**24%**
<-5											
5					80-120	40-60	40-60	40-60	20-30	20-30	20-30
10				80-120	[illegible]-60	40-60	40-60	20-30	10-15	10-15	10-15
15			80-120	40-60	[illegible]-60	20-30	20-30	20-30	10-15	10-15	5-8
20		80-120	40-60	40-60	[illegible]-30	10-15	10-15	10-15	5-8	5-8	3-5
25	80-120	40-60	20-30	20-30	[illegible]-15	5-8	5-8	3-5	3-5	3-5	3-5
30					5-8	3-5	3-5	3-5	3-5	3-5	3-5

Safe storage > a year

NOT SAFE **VERY DANGEROUS**

SAFE STORAGE TIME (days) CEREAL GRAINS

Grain Temp °C	Grain Moisture Content										
	14%	15%	16%	17%	18%	19%	20%	21%	22%	23%	24%
<-5											
5					80-120	40-60	40-60	40-60	20-30	20-30	20-30
10				80-120	[illegible]-60	40-60	40-60	20-30	10-15	10-15	10-15
15			80-[illegible]20	40-60	[illegible]-60	20-30	20-30	20-30	10-15	10-15	5-8
20		80-12[illegible]	[illegible]-60	[illegible]-60	[illegible]-30	10-15	10-15	10-15	5-8	5-8	3-5
25	80-120	40-60	20-30	[illegible]	[illegible]-15	5-8	5-8	3-5	3-5	3-5	3-5
30	40-60	20-30	10-15	10-15	5-8	3-5	3-5	3-5	3-5	3-5	3-5

Safe storage > a year

NOT SAFE

VERY DANGEROUS

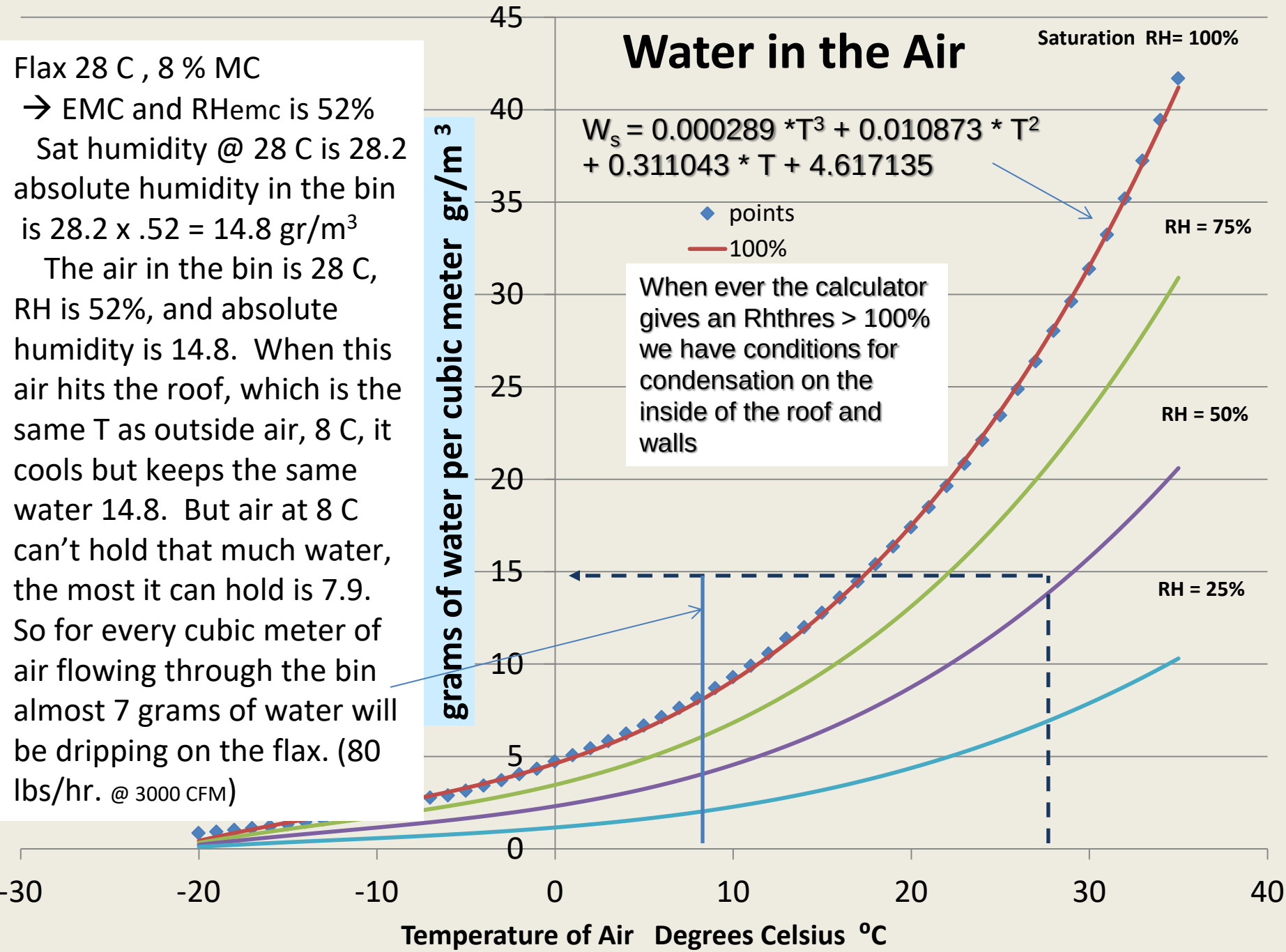
Dripping and Crusting

Flax harvested dry 8% MC, but it is warm 28° C

Nothing is done for a month, but decide to cool it down, by using night drying: yard light rule. Nights are getting cooler and going down to 8°C. Next morning lots of condensation on the inside roof. Did drying at night add water? Or, where did the water come from? The flax was dry?

Plug numbers into calculator, 8% 28 C 8 C and we get 186% for TH_{thres}. What's going on here? How can an RH be greater than 100% ??

Flax 28 C , 8 % MC
→ EMC and RHemc is 52%
Sat humidity @ 28 C is 28.2
absolute humidity in the bin is 28.2 x .52 = 14.8 gr/m^3
The air in the bin is 28 C, RH is 52%, and absolute humidity is 14.8. When this air hits the roof, which is the same T as outside air, 8 C, it cools but keeps the same water 14.8. But air at 8 C can't hold that much water, the most it can hold is 7.9. So for every cubic meter of air flowing through the bin almost 7 grams of water will be dripping on the flax. (80 lbs/hr. @ 3000 CFM)

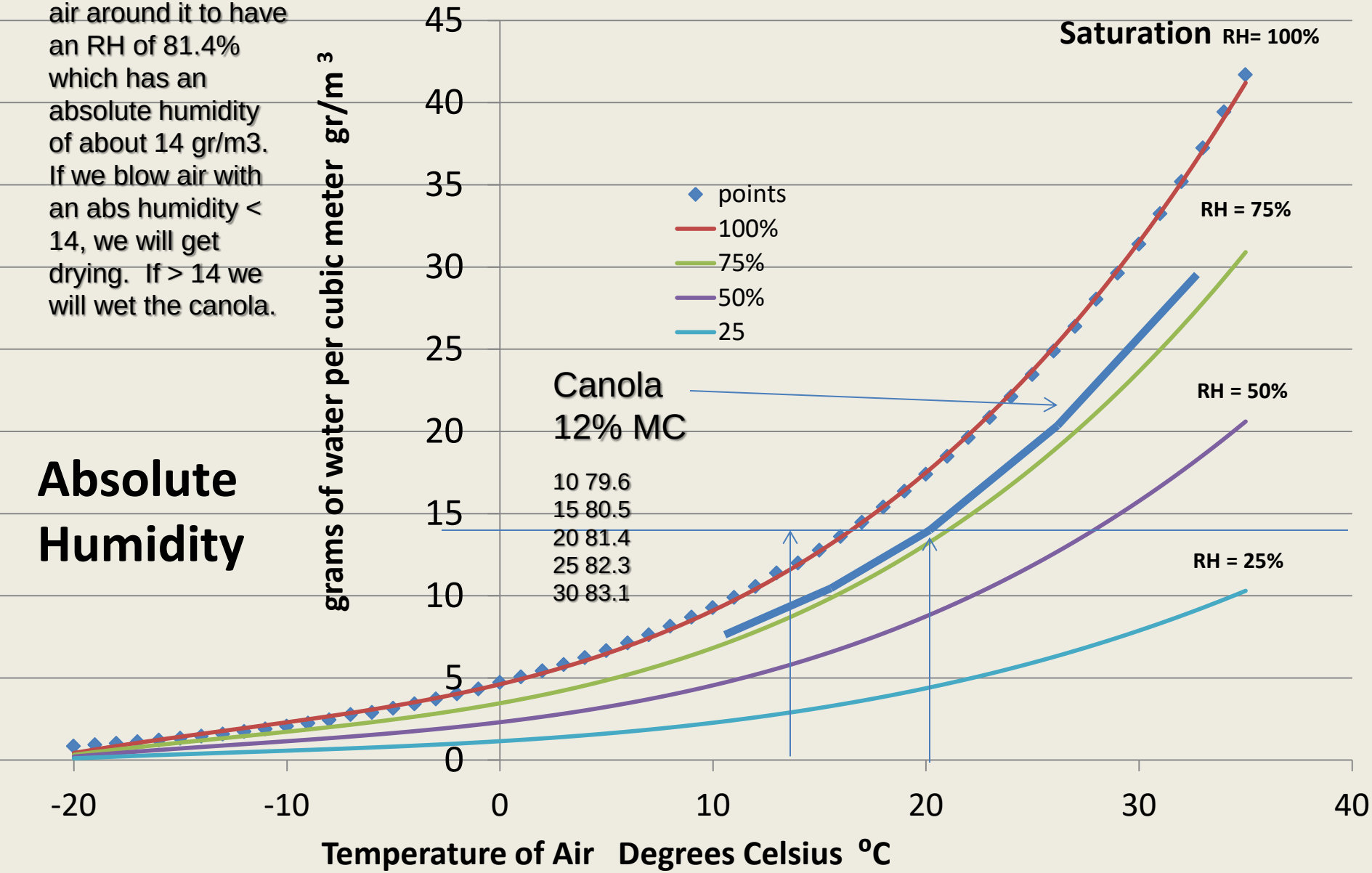


Condensation

- Rule of Thumb: If the grain is warmer than the outside air by more than 5 or 6 ^{o}C there will be condensation.
- If the calculator gives a RH thres of 100% or more you will get condensation.

Water in the Air

Consider Canola @ 12 % MC and 20 C It will equalize the air around it to have an RH of 81.4% which has an absolute humidity of about 14 gr/m3. If we blow air with an abs humidity < 14, we will get drying. If > 14 we will wet the canola.



Supplemental Heat

- Want to dry without condensation
- Ideally want the top layer of grain to be no more than 6 ^{o}C warmer than the outside air.
- Can use the calculator to keep RH thres < 100
- Warming starts at the bottom and takes many hours to get to the top. The outside temp is changing, and it is hard to stay ahead of the curve.
- Plenty of supplemental heat calculations on my blog grain-aeration.com

- Farmer, purchased a diesel heater, 75,000 btu/hr. into a 5000 bushel bin - 3 HP fan.
- Grain was 2 – 3% above dry Temperature Sensors every 4’
- Heat left on continuously, or cycled heating / cooling ?
- Cycling - heater on (75,000 btu/hr) until first 3 or 4 bottom sensors to 25 C. Then cooled the grain, using cold night air (5 C) got the grain down to 10 . After a couple of cycles, he moved the entire contents of the bin to another bin. tipping? If the grain was still not dry he would go through another cycle.
- Cycling much better than continuous. Why – vapour pressure.
- When supplemental heat is applied continuously, the grain becomes more or less the same temperature as the air. As such the vapour pressures of each are more or less the same, and little drying occurs. On the other hand if the grain is warmed, and then cooled with cool or even cold air with very little vapour pressure; there will be lots of water being pushed out of the grain and into the air. Lot's of drying. Back to our old adage "Cooling is drying" and our data indicates our rule of thumb: "For every 15 C that the grain is cooled, 1% moisture will be removed.

Bottom Dries First

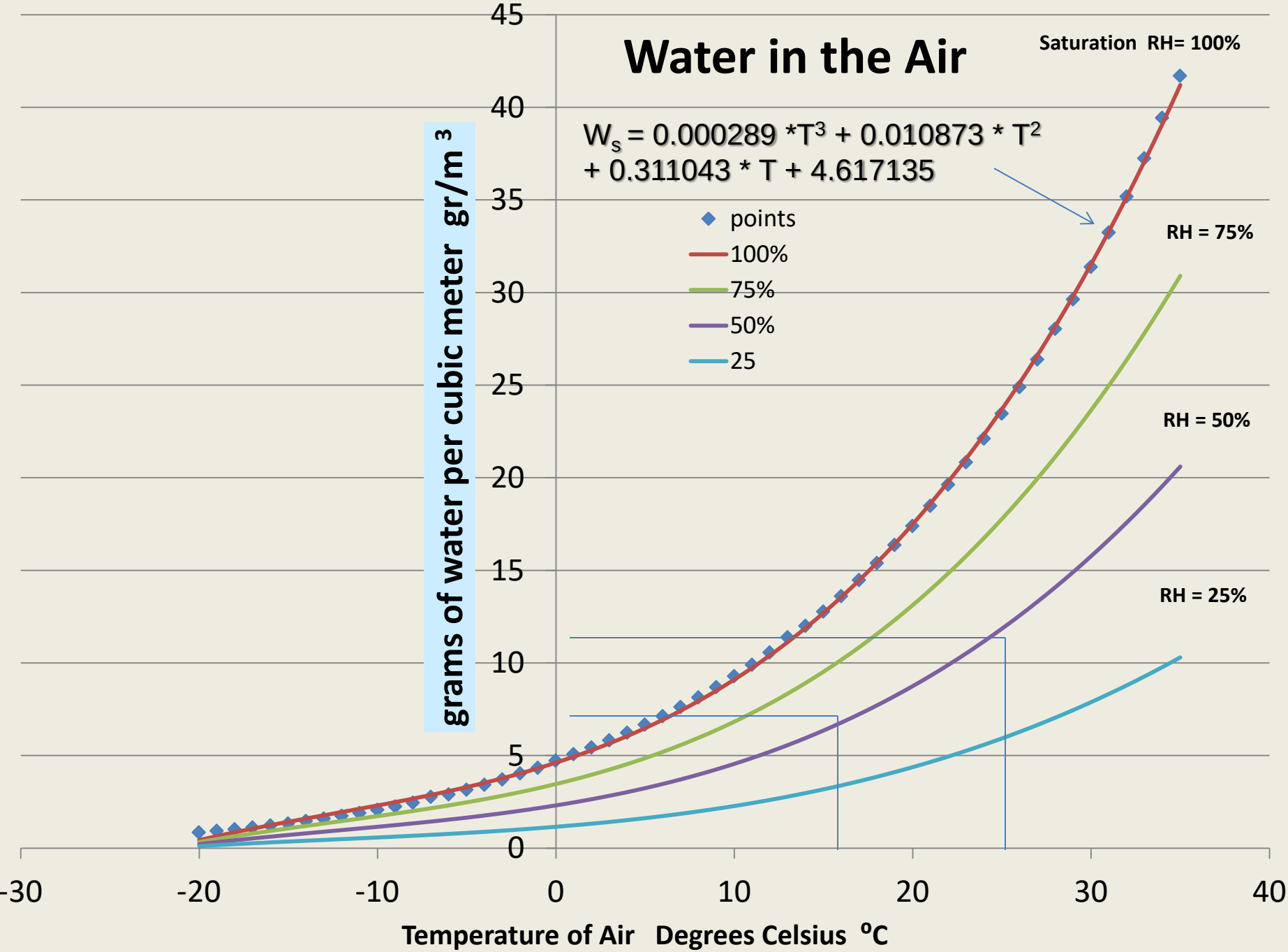
- The fan compresses the air
- Compressing the air, immediately heats it, 3°
- Warmer air can and will hold more water
- As the air rises in the bin it decompresses
- Decompression – cooling
- Cooler Air can’t hold as much water, no drying
- Smaller fans, less compression, less top to bottom difference in drying.

Review
The Black Box Approach

If H_2O IN < H_2O OUT then turn FAN ON (drying)

(AbsHum) (Abs Hum)

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


Water in the Air
Saturation RH= 100%
$W_s = 0.000289 * T^3 + 0.010873 * T^2 + 0.311043 * T + 4.617135$
points
100%
75%
50%
25
RH = 75%
RH = 50%
RH = 25%
grams of water per cubic meter gr/m 3
Temperature of Air Degrees Celsius °C
45
40
35
30
25
20
15
10
5
0
-30
-20
-10
0
10
20
30
40

First 24 Hours is Critical

Average of 33 Runs 2007 – 2014

First 24 Hours:	Start	End	Difference
Grain Temp ^{o}C	26.2	14.6	11.6
Moist Cont %	17.65	16.77	0.88
Safe Days	6	32	26
Cooling/Drying	11.6/0.88 = 13.18 ^{o}C/%MC		

New Definition: Spoilage Index = Σ (1/ safe days) x 100

Example, if safe days is six, then after 3 days we will have an accumulated deterioration of: (1/6 + 1/6 + 1/6) x 100 = 50%,
after 6 days : (6 x 1/6) x 100 = 100% of the way to 95% germination

Recommendations

- In all cases, the fan should be turned on when filling and left running until 9 AM the next day to cool the grain, -- even if it is dry.

Night Drying

- This is for the farmer who has no sensors – not even temperature, and not planning on getting any.
- Mindset = Get the grain as cold as possible, even if it is dry, Cold = Safe

Fan On if Outside Air T < Grain T

- This requires knowledge of the grain temp, but not much more.
- This strategy will keep your grain the safest, because it will keep it the coldest.
- May want to further qualify with < 85% RH
- Cooling is Drying

Fan On: AbsHum Air < AbsHum Grain Air

- Based on the idea that you will only turn the fan on if drying conditions exist.
- Absolute Humidity from Temp and Rel Humid
- Grain Drying Calculator
- Relative Humidity of the Grain Air can be measured directly, or calculated from EMC
- Ultimate strategy, but there is a degree of error in determining RH of grain air.

Seal the Bin

- All the strategies will produce grain that is cold and after you get your grain as cold as possible (-30 ^{o}) VERY SAFE Seal all bin openings to:
  - Hold the cold in
  - Prevent warm spring breezes circulating around your grain with condensation
- Grain will slowly warm up (1 ^{o}C per week)
- Keep pulling grain temp down “Keep it as cold as possible”

Questions?

planetcalc.com/4959/

Grain-Aeration.com

Ron.palmer@uregina.ca

Farmer's Canola Bin →
Kelvington Sask
1600 bushels
Dec 11, 2016