New Insights into Natural Aeration Grain Drying Systems

IHARF Winter Seminar
Melville Communiplex
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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

Air surrounding kernel

Water trying to get in
= Vapour Pressure Air
- temperature
- relative humidity

Grain kernel

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
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

Black Box = Grain Bin

H₂O IN → H₂O OUT

If H₂O OUT > H₂O IN then FAN ON (drying)

If H₂O IN > H₂O OUT then FAN OFF (wetting)
Ibs Water OUT – Ibs 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, i.e., there is more water that went in than came out; then the water must have gone into the grain :: WETTING

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?
Maximum Amount of Water that 6000 cu ft of Air Can Hold

**lbs water @100%RH**

- 12.84 lbs at 90°F
- 9.5 lbs at 80°F
- 5 lbs at 60°F
- 2.5 lbs at 40°F
- 1 lb at 20°F

**Psychrometric Chart**

- Table
- Formula

**Saturation**

- 12.84 lbs at 90°F
- 9.5 lbs at 80°F
- 5 lbs at 60°F
- 2.5 lbs at 40°F
- 1 lb at 20°F
H₂O 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 H₂O -> 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

**lbs water @100%RH**

- 9.5 lbs at 80° F 100%
- 4.97 at 60° 100%
- 4.27 lbs at 80° F 45%
- 2.74 lbs at 60°

**Psychrometric Chart**

9.5 x .45 = 4.27
4.97 x .55 = 2.74

**Table**

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<th>Temperature Deg F</th>
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The Black Box Approach

**Black Box = Grain Bin**

- **H₂O IN**: 2.74 lbs at 60°F 55%
  Per 6000 cu ft.

- **H₂O OUT**: 4.27 lbs at 80°F 45%
  Per 6000 cu ft.

If H₂O OUT > H₂O 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
Sampling ports for Grain Moisture

Temperature Probes
Air Tubes for Recording CFM
RH and Temperature Probe On Inside Top of Bin Recording RH and T°.
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.
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Start 2:30 11° to 9:30 AM remove 532 lbs

Add 152 lbs
During next day 19°
Start 5PM 25°C Wheat 15.6%
First Night 500 lbs removed grain cooled 23° to 16°

10 lb/hr would remove 4332 lb
In 134 hours about 60% time
#2 2007 Spr Wheat 4076 lb = 3.4%

Start 1:30PM to 9AM removed 1370 lbs Wheat chilled from 20° to 4°
Outside temp goes to -3°
S23 2010 Wheat #10

Run for 736 hours or 31 days
Remove 7812 lbs water –6.5% = 14.2
Measured moisture = 13.7%

If we run fan only > 10 lbs/hr
Would remove 9977 in 369 hrs

485 lbs removed
5°C midnight RH 60%

Started 2:23 PM  20.7%
532 lbs removed til 9:23 AM, then put 152 lbs in the next day

2:30 PM
26°C 50%RH
Start 12:30 PM to 10:30AM remove 713 lbs water
Wheat goes from 17 to 9°C as outside goes to 7°
Wheat is almost 20% and hot, (almost 30°C), the first night it only goes to 17°C, the grain cools to 20° so the next day we slip by without wetting the grain. Still remove 900 lbs of water.
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)

Pea Bin 10 2009

Grain temp 27 to 13°C

Net 851 lbs
The days had highs from 25 to 30°C.

First couple of nights had lows of 10°C.
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.
By observation it was noted that the temp difference of the discharge air minus the ambient air temp is a close match to the drying.

If the discharge temp (temp of grain) > ambient then FAN ON

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.
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)
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
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.
Let’s try this temperature difference scheme on last year’s run
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.
- It’s 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?