2015 MSU Seed Technology Short Course Proceedings

Daniel Chesser

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Proceedings of the Seed Technology Short Course
Volume 1
Seed Tech 2015: Storing for Quality

This collection is assembled for the convenience of the attendees of the Seed Technology Short Course and is not peer-reviewed. All content is the work of the identified author.

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Division of Agriculture, Forestry, and Veterinary Medicine
Extension
Mississippi Agricultural and Forestry Experiment Station

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Contributors

Dr. Bill Herndon

Clark Beverage Group of Starkville
Seed Technology Short Course Planning Team
Bill Herndon, DAFVM          Bennie Keith, Director, MCIA
Ernie Flint, Extension      Dennis Reginelli, Extension
Randy Vaughan, MAFES        Jason Ward, Extension

Mississippi State University Administrators
Mark Keenum, President
Gregory Bohach, Vice-President – Division of Agriculture, Forestry, Veterinary Medicine
Bill Herndon – Associate Vice-President, Division of Agriculture, Forestry, Veterinary Medicine
George Hopper – Dean and Director, CALS/MAFES and CFR/FWRC
Wes Burger, Associate Director, MAFES
Gary Jackson, Director, Extension
Steve Martin, Associate Director, Extension – Agriculture and Natural Resources
Mike Philips, Department Head, Plant and Soil Sciences
Jonathan Pote, Department Head, Agricultural and Biological Engineering
Tuesday, August 4, 2015
10:00 Welcome and Introduction
10:15 Seed Maturation and Physiological Maturity – Randy Vaughan, MSU Foundation Seed
11:00 Harvest Aids – Trent Irby, MSU Extension Soybean Specialist
11:30 Harvest Management – Dennis Reginelli, MSU Extension
12:00 Lunch – Mr. Charlie’s Catering Service
1:00 Principles of Seed Storage – Randy Vaughan, MSU Foundation Seed
1:45 Moisture, Measurement, and Psychrometrics – Joe Jacobsen, Jacobsen Holz Corporation
2:30 Break
2:45 Seed Damage and Pre-Cleaning – Marcus Carter, LMC Manufacturing
3:15 Sampling, Grading, and Testing – David Stimpson, Dow AgroSciences
4:00 Q & A Panel
5:00 Adjourn
6:00 Social / Dinner – Sponsored by LMC Manufacturing

Wednesday, August 5, 2015
8:00 Principles of Seed Drying – Joe Jacobsen, Jacobsen Holz Corporation
8:45 Bulk Storage Systems – David Stimpson, Dow AgroSciences
9:30 Aeration and Airflow – Steve Waechter, Sukup Manufacturing
10:15 Break
10:30 Automation and Sensors – Todd Sears, IntelliFarms LLC
11:15 Postharvest Pest Management – Kathy Flanders, Auburn University Extension Entomologist
12:00 Lunch – Mr. Charlie’s Catering Service
1:00 Species Specific Seed Storage Topics A – Choose: corn, wheat, rice, soybeans
   Corn: Joe Jacobsen; Wheat: David Stimpson; Rice: Ernie Flint; Soybeans: Bennie Keith
3:00 Break
3:15 Safety – John Hubbard, MS Farm Bureau
3:45 Q&A Panel
4:45 Summary, Closing, Evaluation
5:00 Adjourn
Seed Maturation and Physiological Maturity

Randy Vaughan
MSU Foundation Seed Stocks
Two most important general objectives in an agricultural crop production?

1. Maximum **yield**
2. Maximum **quality**
   A. (Seed) …… Maximum Germination / Vigor, Purity
   B. (Grain) …… Minimal physical damage / minimal deterioration
      …… Maximum test weight
How are we to most effectively manage crop harvest with the goal of preserving as much yield with quality as possible?
Timely harvest is a major factor
Physiological maturity:

- The stage of seed maturity in which maximum growth (dry weight) is reached and maximum germination / vigor is achieved.
Since seed quality is at a premium at physiological maturity, it would be ideal if we were able to harvest at this stage, ......

..... however, it’s not practically feasible to do so.
Physiological maturity for most crop species, occurs from 40% ---- 30% seed moisture content

........ seed at these moisture levels cannot be efficiently harvested and safely handled
So if we must wait past physiological maturity to harvest, …… how mature is mature enough?
There are early and obvious visual indicators of approaching harvest maturity:
Loss of green color in the leaves and grain (wheat, rice)
Loss of green color from the leaves and pods, seeds shrink and separate from pod wall (soybeans)
Loss of most green color from the leaves and shucks, black layer reached (corn)
As these visual indicators are seen, we should begin to carefully track falling seed moisture levels.
At what specific seed moisture content harvest should begin is a complex question?

• Depends upon crop species
At what specific seed moisture content harvest should begin is a complex question?

- Depends upon crop species
- Depends upon whether harvest is for seed or grain
At what specific seed moisture content harvest should begin is a complex question?

- Depends upon crop species
- Depends upon whether harvest is for seed or grain
- Depends on how long it will take to accomplish harvest
At what specific seed moisture content harvest should begin is a complex question?

- Depends upon crop species
- Depends upon whether harvest is for seed or grain
- Depends on how long it will take to accomplish harvest
- Depends upon the amount of time required to hold and transport the bulk seed mass to the drying facility
At what specific seed moisture content harvest should begin is a complex question?

• Depends upon crop species
• Depends upon whether harvest is for seed or grain
• Depends on how long it will take to accomplish harvest
• Depends upon the amount of time required to hold and transport the bulk seed mass to the drying facility
• Depends upon the speed and efficiency of the drying equipment
Harvesting too soon (high seed moisture) leads to:

• Harvest efficiency problems (too much green material)
• Seed bruising / impact damage
• Difficulty in safe / efficient drying
Harvesting too late (low seed moisture) leads to:

- harvest efficiency problems (shattering losses)
- seed impact damage / cracking or breaking
- reduced seed quality if crop “weathered” during delay
- reduces yield volume by weight
Maturation of Soybean:

Physiological Maturity
R - 6.5

--------------------- (2 - 3 weeks) ----------------------

Harvest Maturity
R - 8
Physiological Maturity
(Maximum growth / dry weight)
(Maximum germination potential)

Harvest Maturity
Earliest point when sufficient seed moisture is lost to allow for safe mechanical harvest

Seed Development

Seed Moisture Content
Germination

Post maturity / Pre-harvest Window

How fast quality falls after physiological maturity depends upon environment and species
Once physiological maturity has been reached, the two main principles in preserving both maximum yield and maximum quality in a seed crop (both pre-harvest and post-harvest) are the **environmental factors** of ...........

- Temperature
- Moisture
Across all seed kinds …..mild temperature and low relative humidity is the preferred environment during the post maturity / pre-harvest period.

But, we don’t always enjoy such conditions during this time.
Since average air temperatures and moisture levels vary significantly by month, the timing of seed maturity can have a substantial impact upon seed health / quality.
Probability of precipitation at some point in the day

Weatherspark.com (Columbus, MS)
Dew Point (Columbus, MS)

Weatherspark.com
Daily High and Low Temperature

Weatherspark.com (Columbus, MS)

Day time

Night time
Soybean maturation in north/central Mississippi

PM: Physiological Maturity
HM: Harvest Maturity

Group III
PM: August
HM: AVG 82 F 70% RH

Group V
PM: October
HM: AVG 65 F 50% RH
**Temperature and Relative Humidity** levels play a crucial role in preservation of quality from the time of physiological maturity until harvest can take place.

**Wheat** Harvest Window: **June**
- Weather: Sunny (Hot, Somewhat humid)
- Weather: Frequent Rains (Warm, Very humid)

**Physiological Maturity**
- Average 85 F
- 75% RH

**Harvest Maturity**
- Less forgiving harvest period, generally brief (7-10 days)

**Soybean** Harvest Window: **October**
- Weather: Sunny (lower temp, less humid)
- Weather: Frequent Rains (Cooler, but humid)

**Physiological Maturity**
- Average 70 F
- 60% RH

**Harvest Maturity**
- More forgiving harvest period, generally longer (14-21 days)
Seeds are very susceptible to adverse environmental field conditions anytime during the period \textit{after physiological maturity} ......and only continues after initial harvest maturity.

- The primary negative factor is moist conditions, … (rain, fog, cloud cover). Warm weather only serve to compound the detrimental effects of wet conditions.
Working together, moist/warm conditions in a field at the harvest maturity stage is the perfect environment for ....

- development of fungus / molds
Working together, moist/warm conditions in a field at the harvest maturity stage is the perfect environment for ....

- development of fungus / molds
- decreased test weights
Working together, moist/warm conditions in a field at the harvest maturity stage is the perfect environment for:

- development of seed molds
- decreased test weights
- decreased germination and seed vigor
Working together, moist/warm conditions in a field at the harvest maturity stage is the perfect environment for ....

- development of seed molds
- decreased test weights
- decreased germination and seed vigor
- death of the seed
Working together, moist/warm conditions in a field at the harvest maturity stage is the perfect environment for ....

- development of seed molds
- decreased test weights
- decreased germination and seed vigor
- death of the seed

* Issues are compounded further when the crop is in a **lodged condition**
When the micro-environment around the seed is restricted to air movement and sunshine, the seed remain in highly humid conditions both night and day.
During the (post-maturation pre-harvest) time period …..

<table>
<thead>
<tr>
<th>As temps and humidity rise ..</th>
<th>As temps and humidity fall ..</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Seed moisture rises</td>
<td>• Seed moisture falls</td>
</tr>
<tr>
<td>• Respiration increases</td>
<td>• Respiration decreases</td>
</tr>
<tr>
<td>• Seed diseases increase</td>
<td>• Seed diseases decrease</td>
</tr>
<tr>
<td>• <strong>Seed health is diminished</strong></td>
<td>• <strong>Seed health is preserved</strong></td>
</tr>
</tbody>
</table>
Fall weather pattern
Scenario #1:
Initial Harvest Maturity

Following Repeated Wet/Dry Cycles

Germination

Seed Moisture

Time

%
Fall weather pattern
Scenario # 2
Harvest delayed due to …
- Labor required elsewhere
- Equipment required elsewhere
- Equipment breakdown
- Not paying attention

Harvest Delayed -again

Prolonged wet period: multiple rains, overcast days, drizzle, fog, warm, humid

Weather clears crop / field dry

Harvest Accomplished
Harvest promptly at initial harvest maturity, and provided weather conditions have been favorable during the moisture dry down period, ….. you can generally expect results like this..
If harvest is delayed, and you experience poor conditions (warm / wet) you will be more likely to experience this . . .
In a fall where the crop has not lodged and you have long periods of consistent good weather (moderate --- cool temps, little rainfall, low humidity, clear skies), ….. then moderate harvest delays are not as critical.

However  .................
How many years do we have “ideal” falls where harvest weather is concerned?

…. cool and dry conditions for many consecutive weeks following initial harvest maturity?

Not many!
Frequently, we will experience at least some unfavorable weather not long after initial harvest maturity.

Some years we will experience several periods of poor weather following initial harvest maturity.

On occasion, ....... we will have a year like 2009.
Be aware that even when harvest maturity is reached in the field, there are numerous day-to-day environmental factors that cause fluctuations in seed moisture content:

- Dew
- Wind velocity
- Length of continuous sunshine period
- Quantity and duration of precipitation
- Species, quantity, size, and maturity of competing weed growth
Green plant material remaining in a harvested seed mass can raise the moisture content and act as a catalyst to create a “heating" threat if not dealt with quickly.
Seeds are hygroscopic: Seeds gain or lose water over time to come into equilibrium with their environment.

Water leaves the seed as a vapor based on the moisture content of the air immediately surrounding the seed.
Seed moisture is in constant flux with surrounding air. The chart below illustrates the seed moisture content equilibrium for various seeds at different percent relative humidities (30% to 90%).

<table>
<thead>
<tr>
<th>Seed Kind</th>
<th>30</th>
<th>45</th>
<th>60</th>
<th>65</th>
<th>70</th>
<th>75</th>
<th>80</th>
<th>85</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorghum</td>
<td>8.6</td>
<td>10.5</td>
<td>12.0</td>
<td>13.0</td>
<td>---</td>
<td>15.2</td>
<td>---</td>
<td>---</td>
<td>18.8</td>
</tr>
<tr>
<td>Soybean</td>
<td>6.5</td>
<td>7.4</td>
<td>9.3</td>
<td>11.0</td>
<td>---</td>
<td>13.1</td>
<td>16.0</td>
<td>---</td>
<td>18.8</td>
</tr>
<tr>
<td>Rice</td>
<td>9.0</td>
<td>10.7</td>
<td>12.6</td>
<td>---</td>
<td>---</td>
<td>14.4</td>
<td>16.0</td>
<td>---</td>
<td>18.1</td>
</tr>
<tr>
<td>Corn</td>
<td>8.4</td>
<td>10.5</td>
<td>12.9</td>
<td>13.0</td>
<td>---</td>
<td>14.8</td>
<td>15.0</td>
<td>---</td>
<td>19.0</td>
</tr>
<tr>
<td>Wheat</td>
<td>8.6</td>
<td>10.6</td>
<td>11.9</td>
<td>---</td>
<td>---</td>
<td>14.6</td>
<td>---</td>
<td>---</td>
<td>19.7</td>
</tr>
</tbody>
</table>

Seed moisture is in constant flux with surrounding air.
As harvest approaches, (although weather conditions are always unpredictable), ……... advance planning and key management decisions contribute significantly to a quality seed harvest outcome.
A high quality seed / grain outcome frequently comes down to issues such as …….

- Adequate resources
  - Field equipment (can you accomplish multiple harvests simultaneously)
  - Drying and Storage Facilities
  - Trained and available labor
A high quality seed / grain outcome frequently comes down to issues such as ........

- **Adequate resources**
  - Field equipment (can you accomplish multiple harvests simultaneously)
  - Drying and Storage Facilities
  - Available labor

- **Advance planning** (Timely ending of irrigation, stagger crop maturities)
A high quality seed / grain outcome frequently comes down to issues such as ……..

- Adequate resources
  - Field equipment (can you accomplish multiple harvests simultaneously)
  - Drying and Storage Facilities
  - Available labor
- Advance planning (Timely ending of irrigation, stagger crop maturities)
- Timely management decisions (Monitor crop/field conditions closely)
A high quality seed / grain outcome frequently comes down to issues such as ........

• Adequate resources
  – Field equipment (can you accomplish multiple harvests simultaneously)
  – Drying and Storage Facilities
  – Available labor

• Advance planning (Timely ending of irrigation, stagger crop maturities)

• Timely management decisions (Monitor crop/field conditions closely)

• Priorities (Example: Wet weather approaches and you need to plant soybeans, but you also need to harvest wheat, …… what choice will you make?)
It is important to realize that once physiological maturity has been reached, quality (germination / vigor / test weight) can only be preserved, never restored after it has been lost.

Once seed / grain deterioration has occurred, the condition is irreversible.
Evaluating seed maturity:

Seed collected from the same head

Seed Moisture Content
Seed moisture variability:

15% 35%
Obtaining Seed Moisture Readings:
Ensure that seed moisture testers are properly calibrated.

It can be risky to assume that factory calibrations are reliable.
When collecting moisture samples, ensure that your results are **representative**: 

- Collect and test samples at the time of day harvest will begin
When collecting moisture samples, ensure that your results are **representative**:

- Collect and test samples at the time of day harvest will begin
- Collect and test samples from fruiting positions representing the entire plant(s)
When collecting moisture samples, ensure that your results are representative:

- Collect and test samples at the time of day harvest will begin
- Collect and test samples from fruiting positions representing the entire plant(s)
- Collect and test samples from numerous locations in the field (Average results)
Ensure that the moisture sensors on the combine are also correctly calibrated so that you can track any changes through time during the day.
Remember, avoid waiting until seed moistures have fallen below minimum ranges, since doing so leads to mechanical damage to the seed caused by harvesting equipment.
Seed moisture content for harvest:

<table>
<thead>
<tr>
<th>Crop</th>
<th>Max (grain)</th>
<th>Min (grain)</th>
<th>Max (seed)</th>
<th>Min (seed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>25</td>
<td>17</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Soybean</td>
<td>16</td>
<td>13</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Rice</td>
<td>21</td>
<td>17</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td>Wheat</td>
<td>20</td>
<td>14</td>
<td>17</td>
<td>13</td>
</tr>
</tbody>
</table>
End
Soybean Harvest Aids

Trent Irby
Extension Soybean Specialist
Soybean Harvest Aids

- Desiccate late-emerging weeds to facilitate harvest
- Progresses drying of immature plants
- Potentially combat issues with green stem
Soybean Harvest Aids

- Foreign material and added moisture can reduce crop quality and profitability
- Late season harvest may experience issues with weather and combine efficiency
Soybean Growth Habits

• Indeterminate varieties
  • Begin reproduction at bottom of plant and progress upwards as plant produces more nodes

• Determinate varieties
  • Flower uniformly up and down the plant
# Soybean Harvest Aids

<table>
<thead>
<tr>
<th>Product</th>
<th>Rate</th>
<th>Timing</th>
<th>PHI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aim</td>
<td>1-1.5 fl oz</td>
<td>65% brown pods</td>
<td>3 days</td>
</tr>
<tr>
<td>paraquat</td>
<td>0.25 lb ai</td>
<td>65% brown pods</td>
<td>15 days</td>
</tr>
<tr>
<td>Sharpen</td>
<td>1-2 fl oz</td>
<td>65% brown pods</td>
<td>3 days</td>
</tr>
<tr>
<td>sodium chlorate</td>
<td>3-6 lb ai</td>
<td>7-10 days before harvest</td>
<td></td>
</tr>
</tbody>
</table>
## Harvest Aid Treatments

<table>
<thead>
<tr>
<th>Product</th>
<th>Rate (Acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gramoxone SL</td>
<td>1 pt</td>
</tr>
<tr>
<td>Gramoxone SL + Sharpen</td>
<td>+ 1.0 oz</td>
</tr>
<tr>
<td>Gramoxone SL + sodium chlorate</td>
<td>+ 3 lb ai</td>
</tr>
<tr>
<td>sodium chlorate</td>
<td>6 lb ai</td>
</tr>
<tr>
<td>Sharpen</td>
<td>1.5 oz</td>
</tr>
</tbody>
</table>

*All surfactants added per label recommendations*
Results

% Desiccation

Gramoxone SL  Gramoxone SL  Gramoxone SL  sodium chlorate  Sharpen
+ Sharpen       + sodium chlorate

3 DAT  7 DAT

A  A  B  A  B  A  C  A
At time of application…
Gramoxone SL @ 1 pt

3 DAT

7 DAT
Gramoxone SL @ 1 pt + Sharpen @ 1oz

3 DAT

7 DAT
Gramoxone SL @ 1 pt + sodium chlorate @ 3 lb ai
sodium chlorate @ 6 lb ai

3 DAT

7 DAT
Sharpen @ 1.5 oz

3 DAT

7 DAT
Soybean Yield

![Bar graph showing the yield of different treatments. The x-axis represents the treatments: Gramoxone SL, Gramoxone SL + Sharpen, Gramoxone SL + sodium chlorate, sodium chlorate, and Sharpen. The y-axis represents the yield in bu/A. The graph shows the yield for each treatment, with Gramoxone SL + sodium chlorate having the highest yield.]
Results and Discussion

• Gramoxone SL was more effective than Sharpen 3 DAA
• Neither reached 100% desiccation 3 DAA
Results and Discussion

• Both Gramoxone SL and Sharpen were desiccated to a harvestable state 7 DAA

• Only Sharpen has met PHI at this time
Conclusions

• Gramoxone SL, Sharpen, and sodium chlorate are all effective harvest aid options in soybean

• Sharpen application may require longer than 3 days (PHI) after application to reach full desiccation level
Thanks!

Trent Irby
Extension Soybean Specialist
Phone: 662-418-7842
E-mail: trent.irby@msstate.edu
Harvest Management

Dennis B. Reginelli
Regional Extension Agronomist
Is This Harvest Management?

Grain Quality Traits

Higher Yields
Timely Planting

Days Suitable for Field Work
Planter Power
Travel Distance

Deliver to Elevator or Grain Bin

Storage Capacity
Dryer Capacity
Long or Short term

Visual Inspection
Identify all Cleanout and Inspection Points
Effect of Desiccant on Soybean Moisture

![Graph showing the effect of desiccant on soybean moisture]

- **Y-axis**: Percent Moisture
- **X-axis**: Pitted Morningglory Density (plants/sq m.)
- **Legend**:
  - Red: No Desiccant
  - Yellow: Desiccant

The graph illustrates the amount of moisture in soybeans treated with desiccant compared to those without desiccant treatment. The moisture levels are measured for different densities of Pitted Morningglory.
Harvest Losses

- Start according to manual
- Adjustments should be made incrementally
- Some are single factor adjustments
- Most involve tweaking multiple settings
- Make small individual changes
- There is a moisture sweet spot
Harvest Losses

• Every bushel you save by careful operation of your combine adds to your profit per acre.

• To keep harvesting losses low, You need to know where losses occur.

• Losses as high as 20 bu/acre behind poorly adjusted combine operating in weedy or severely lodged corn.
Equipment Management

- Key Combine Settings
  - Ground Speed
  - Rotor or Cylinder Speed (threshing)
    - 300-600 rpm increases damage 5-30%
    - Leading cause of grain damage
  - Concave Clearance
  - Fan Speed (cleaning)

Combine settings and operation are critical to preserve grain quality.

High quality seed stores well

High quality seed has less risk
Measuring Corn Harvest Losses

Check corn head loss by backing machine up and counting kernels in 10 square foot frames over each row.

Measure cylinder and separation losses here.

Each ¾ lb. ear or equivalent smaller ears left in 1/100 acre equals 1 bu./A.
Pre-Harvest & Cylinder loss

Determine the total ear loss by laying out a 1/100 acre test area immediately behind the combine, as described in the text. Gather the missed ears from all the rows in the test area. Each ¾ lb. ear or equivalent represents 1 bu. per acre loss.

Determine the pre-harvest loss by laying out a 1/100 acre test area in the standing corn in front of the combine, as described in the text. Gather and count the ears on the ground.

Determine the machine ear loss by subtracting the pre-harvest loss from the total ear loss.
How To Measure Losses

<table>
<thead>
<tr>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width (\text{inches})</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>36</td>
</tr>
<tr>
<td>38</td>
</tr>
</tbody>
</table>

- Loss of 2 kernels per square foot = approximately 1 bushel per acre loss.
## Corn Harvesting Loss
### 84 Randomly Selected Combines

<table>
<thead>
<tr>
<th>Loss Type</th>
<th>Avg (bu/acre)</th>
<th>Top 10% (bu/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine ear loss</td>
<td>1.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Stalk roll shelling</td>
<td>0.9</td>
<td>0.3</td>
</tr>
<tr>
<td>Cyclinder loss</td>
<td>0.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Separating Loss</td>
<td>0.7</td>
<td>0.2</td>
</tr>
<tr>
<td>Total harvesting Loss</td>
<td>3.7</td>
<td>0.5</td>
</tr>
<tr>
<td>Preharvest dropped ears</td>
<td>2.1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total Loss</strong></td>
<td><strong>5.8</strong></td>
<td><strong>1.5</strong></td>
</tr>
</tbody>
</table>
Little things make a difference

small decisions impact yield.
What Can We Do Now

• Little things make a difference – small decisions impact yield.
Principles of Seed Storage

Randy Vaughan
MSU Foundation Seed Stocks
Seed Storage losses:

- Worldwide, it has been estimated that about 1/3 of harvested (grain / seed) spoils in storage each year.

  Of that amount, …… there are two main causes:

  1. Poor storage climate environment

  2. Deterioration caused by insects
Just as the environmental air properties of \textit{temperature} and \textit{relative humidity} play key roles in seed maturation and dry-down, …… so they are just as crucial when it comes to the issue of seed storage.
At every stage of their production, ..... it’s important to remember that seeds are living things that must be properly cared for if we want to preserve them.
Unless seeds are at a safe storage moisture content when harvested, ........ (usually not the case) then a narrow window of time exists in which a safe storage moisture can be achieved.
Narrow window of time from seed harvest to point at which safe storage moisture is achieved:

Degree of urgency depends upon:

1. Moisture content of the seed at harvest
   .......... (The higher the seed moisture content, the less time available)
Narrow window of time from seed harvest to point at which safe storage moisture is achieved:

Degree of urgency depends upon:

1. Moisture content of the seed at harvest
2. Speed of drying facility ..... (relative to harvested seed volume) 
       ............ (The slower the speed, ..... the more critical time becomes)
Narrow window of time from seed harvest to point at which safe storage moisture is achieved:

Degree of urgency depends upon:

1. Moisture content of the seed at harvest
2. Speed of drying facility ..... (relative to harvested seed volume)
3. Harvested seed mass temperature
   ........ (The higher the temperature, ..... the less time available)
Narrow window of time from seed harvest to point at which safe storage moisture is achieved:

**Degree of urgency** depends upon:

1. Moisture content of the seed at harvest
2. Speed of drying facility …. (relative to harvested seed volume)
3. Harvested seed mass temperature

* The total amount of time that you have depends upon the interaction and degree of all these factors collectively.
When seed arrive from the field, probe the grain to check the **temperature** and the **seed moisture**.
Remember, samples must be representative

➢ Test every load
  - Test from multiple locations within each load
Don’t let **high moisture** seed stay in the grain trailer overnight.

If the seed is **warm/hot**, it becomes even more urgent.

If there is any doubt, …… always hedge on the side of caution and move the seed immediately to the drying equipment.
In the short run, ....... even if only high humidity ambient air is available, if the air temperature is substantially cooler, the cooling benefit out-ways the risk of elevating the seed moisture content.
As seeds arrive at the drying and storage facility after harvest, remember that they are “thermo-sensitive,” meaning: there are limits to what they can withstand with respect to heat.

Two factors to consider:

1. Degree of temperature .......... how hot?
2. Duration of temperature .......... how long?
Two instances in which high temperature can present a problem with harvested seed.

1. When the seed mass generates heat from natural sources
High moistures are not uncommon when seed arrive from the field, but if not dealt with soon ……..

First: Fungi will develop (as fungus spores grows they respire producing heat and thus cause the seed mass temperature to rise)

Next: If not reversed quickly, the elevated temperatures encourage development of bacteria that also respire and produce even higher temperatures.
“Warm / high moisture” conditions in a seed mass sparks a vicious cycle.
Heat damage to seed immediately following harvest (as well as later on) can occur as a result of the interaction of ……..

• High seed moisture content at harvest
• Natural presence of fungi
• Heat of the seed mass as it comes from the field on a hot day

* Heating process can take as little as 12 - 15 hours to develop (Hill, 1975)
“The storage of seed at an initially high temperature, (whether this occurs as a result of the respiration heating of wet seed or the retention of radiant heat in freshly harvested seed) even though it may be at a moisture content considered safe for storage, can be dangerous in allowing the buildup of *Aspergillus* in the seed to a stage where the fungus continues heat production in the seed mass.”

M.J. Hill and C.R. Johnstone
Seed Technology Center, Massey University, New Zealand
What about potential problems that fungi may present later on in seed storage?
What factors determine if seed will experience damage by fungi in storage?

1. Seed Moisture:
   14% or more will develop problems over time, …… and the higher the moisture, the shorter the amount of time it will take for it to occur.
What factors determine if seed will experience damage by fungi **in storage**?

1. Seed Moisture:
2. Temperature: (Above 80 F, fungi grow rapidly, below 50 F, fungi grow very slowly)
What factors determine if seed will experience damage by storage fungi?

1. Seed Moisture
2. Temperature
3. Amount of fungi spores already present in seed when placed in storage (depends on amount of weathering already experienced in the field)
What factors determine if seed will experience damage by storage fungi?

1. Seed Moisture
2. Temperature
3. Amount of fungi spores already present in seed when placed in storage
4. Degree of mechanical damage to the seed (cracked and broken seed make it easier for fungus to enter the seed)
What factors determine if seed will experience damage by storage fungi?

1. **Seed Moisture:** (13% or less considered safe)
2. **Temperature:** (Above 80 F, fungi grow rapidly, but below 50 F, fungi grow very slowly)
3. **Amount of fungi spores already present in seed when placed in storage**
4. **Degree of mechanical damage to the seed**
5. **Length of the storage period** (The longer the storage period, .... the more at risk seed are to fungus growth and damage)
Depending on degree and duration of “heating,” the results to the seed can be:

1. Loss of germination and vigor
2. Fungi develop and produce poisonous compounds called “mycotoxins”

* One of the most common mycotoxins is aflatoxin, a known cancer causing agent.

Seed mass “heating” can thus destroy both the seed value and commodity value of stored seed.
Two instances in which high temperature can present a problem with harvested seed.

1. When the seed mass generates heat from natural sources

2. When excessive levels of artificial heat are introduced through the drying system
Supplemental (artificial) heat limits:

- **For grain:** Air temperatures should not exceed 140°F to avoid damage to milling quality.

- **For seed:** Air temperatures should not exceed 110°F to avoid damage to seed viability.

  - Some species (vegetables, small seeded legumes) are even more delicate and should not be dried with air heated above 95°F.
To minimize heat injury potential, cool the seed after drying with heated air.

To cool, ....... turn off the heater and allow the fan to operate with ambient air for a short time until the grain is cooled to the ambient temperature.
Consequences of over-drying seed, ..... either by too much total drying or drying too rapidly:

1. Causes physical damage
   > Cracked seed coats
   > Stress cracks through embryo, cotyledons, or endosperm
Consequences of over-drying seed, ..... either by too much total drying or drying too rapidly:

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2. Increases susceptibility of mechanical damage in future handling (movement) of seed
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1. Causes physical damage
   - Cracked seed coats
   - Stress cracks through embryo, cotyledons, or endosperm

2. Increases susceptibility of mechanical damage in future handling (movement) of seed

3. Loss in germination, vigor

4. Negative economic impact
   - excessive water loss translates to excessive weight loss
## Issues to remember as related to seed moisture:

<table>
<thead>
<tr>
<th>Seed moisture</th>
<th>Condition of Seed after maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 – 9%</td>
<td>Mechanical damage to seed more likely</td>
</tr>
<tr>
<td>10-13%</td>
<td>Optimum for storage, handling, and packaging.</td>
</tr>
<tr>
<td>14-16%</td>
<td>Harmful molds (fungi) may develop on seeds in storage.</td>
</tr>
<tr>
<td>17-20%</td>
<td>Seed may heat due to high respiration and microbial activity. (seed germination, vigor decline rapidly)</td>
</tr>
<tr>
<td>21% +</td>
<td>Seeds decay (rot)</td>
</tr>
<tr>
<td>40-60%</td>
<td>Germination begins</td>
</tr>
</tbody>
</table>
The details of seed drying as well as how to continuously monitor seed and grain temperatures in bulk storage will be discussed by a later speakers, ........

However, … we should address at this point some essential concepts related to successful bin storage.
Remember, **seeds are hygroscopic**: Seeds gain or lose water over time to come to equilibrium with their environment.

This is not only true when trying to dry the seed, but thereafter when they are in storage as well.
We can’t assume that once the seed in the bin have been dried to a safe moisture content level, that it will stay that way!

Just as seed dried when it was exposed to the correct air properties in the field and in the bin, .... when those air properties increase in moisture over time, ... then the seed moistures will start to rise again.
Seed moisture is in constant flux with surrounding air.

<table>
<thead>
<tr>
<th>Seed Kind</th>
<th>Percent Relative Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Sorghum</td>
<td>8.6</td>
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<tr>
<td>Soybean</td>
<td>6.5</td>
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<tr>
<td>Rice</td>
<td>9.0</td>
</tr>
<tr>
<td>Corn</td>
<td>8.4</td>
</tr>
<tr>
<td>Wheat</td>
<td>8.6</td>
</tr>
</tbody>
</table>
“Seed Drying” --- vs ---- “Seed Aeration”

What’s the difference?

• **Seed drying**: Forced (altered air property) flow through a seed mass for the purpose of **reducing** seed moisture content.

• **Seed aeration**: Forced (ambient) air flow through a seed mass for the purpose of **maintaining** seed storage moisture content.

  • *(Ambient)*: Natural atmosphere conditions.
When to “aerate” seed:

1. If there is a temperature difference of 20 degrees F or more between the seed mass and the ambient conditions.

(Condensation of free water can occur in or on the seed)
When to “aerate” seed:

1. If there is a temperature difference of 20 degrees F or more between the seed mass and the ambient conditions.
   (Condensation of free water can occur in or on the seed)

2. If there are temperature differences of 5 degrees F or more within the seed mass.

- Example: When partial volumes of a seed production arrive at different times, …… even if the moisture content is acceptable, …… If there is a substantial temperature difference, ….. then aerate seed.
If the seed mass is already dry, but aeration is needed to maintain the safe seed moisture level, the ambient air must have …..the **correct relative humidity**.
Example: If you have wheat seed in the bin that you are trying to hold at 12% moisture ...........

<table>
<thead>
<tr>
<th>Species</th>
<th>15</th>
<th>30</th>
<th>45</th>
<th>60</th>
<th>75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>6.8%</td>
<td>9.0</td>
<td>10.7</td>
<td>12.6</td>
<td>14.4</td>
</tr>
<tr>
<td>Wheat</td>
<td>6.3</td>
<td>8.6</td>
<td>10.6</td>
<td><strong>11.9</strong></td>
<td>14.6</td>
</tr>
<tr>
<td>Soybean</td>
<td>4.3</td>
<td>6.5</td>
<td>7.4</td>
<td>9.3</td>
<td>13.1</td>
</tr>
</tbody>
</table>

* To hold moisture of wheat at 12% or below, you must only run bin fan at 60% RH or below, ............ (however, if the RH is lower than 60%, excess drying will occur)
Daily relationship pattern between temperature / relative humidity on a sunny --- partly cloudy day:

As temperature rises, ........ relative humidity decrease
Keeping up with current relative humidity values is easy.

Just make sure the data you receive is close to real time information.
While through proper management we can do much to preserve seed quality, deterioration of seed in storage is both ...........

...... **Unavoidable**
   - Seed quality will deteriorate over time

...... **Irreversible**
   - Any seed deterioration that does occur cannot be undone.
Factors that determine the “rate” of seed deterioration in storage:

1. **Quality** of seed when it enters storage
   (High quality seed deteriorate more slowly than poor quality seed)

   * If seed vitality has been diminished prior to its entering cold storage, the benefit that otherwise would have been realized by good storage conditions will not be realized.
Factors that determine the “rate” of seed deterioration in storage:

1. Quality of seed when it enters storage
   > High quality seed deteriorate more slowly than poor quality seed

2. Speed at which good storage conditions are obtained  (low temp / low RH)
Factors that determine the “rate” of seed deterioration in storage:

1. **Quality** of seed when it enters storage
   > High quality seed deteriorate more slowly than poor quality seed
2. **Speed** at which good storage conditions are obtained
3. **Whether good storage conditions are maintained**
   - seed left in bin, warehouse, …… or moved to cold storage
Factors that determine the “rate” of seed deterioration in storage:

1. **Quality** of seed when it enters storage
   > High quality seed deteriorate more slowly than poor quality seed
2. **Speed** at which good storage conditions are obtained
3. Whether good storage conditions are maintained
4. **Length** of the storage period
   > The longer the storage, the more deterioration will occur
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3. Whether good storage conditions are **maintained**
4. **Length** of the storage period
   > The longer the storage, the more deterioration will occur
5. **Species** of the seed
Some crop species store better than others:

• High starch species: Store well for long periods
  – (corn, wheat, rice, sorghum)

• High oil species: Do not store well over long periods
  – (soybeans, peanuts)
Storage comparison of Corn to peanuts:
(Overall 10% seed moisture content for each species)

- Corn: seed made up of only 5% lipids
- Peanut: seed made up of 48% lipids

Corn: \[ \frac{10}{.95} = .1053 \times 100 = 10.5\% \text{ (seed moisture stored in non-lipid portion)} \]

Peanut: \[ \frac{10}{.52} = .1923 \times 100 = 19.2\% \text{ (seed moisture stored in non-lipid portion)} \]
Looking at this from the other side, ........ if we would like to see what seed moistures we would need to have equivalent storage conditions (at 13%) for both corn and peanuts, ........ we can do so as follows.

Corn:  95% non-lipid composition
Peanut:  52% non-lipid composition

Corn:  $0.13 \times 0.95 = 0.1235 \times 100 = 12.35\%$

Peanuts:  $0.13 \times 0.52 = 0.0676 \times 100 = 6.76\%$
Rules of thumb for seed storability:

- Between 14% --- 5% seed moisture: Each 1% reduction in seed moisture content doubles seed storage longevity. (Harrington, 1960)

- Each 10°F reduction in storage temperature, doubles seed storage longevity. (Harrington, 1960)

70 degrees F: Seed lot stores for one year at 90% germination

60 degrees F: Same seed lot should store well for two years
Climate controlled storage:
We have already established that the keys to seed health and vitality, ….. at any stage from physiological maturity forward, ….. are low temperature and low relative humidity.

Climate controlled storage (cold storage) allows for the opportunity to artificially enhance the environment of seeds in order to preserve and extend seed health and vitality.
Climate controlled storage is most commonly utilized when………

- The seed **volume** is manageable
- The seed is to be stored for a considerable length of **time**
- The seed is of **high value** / importance
Practical standards for cold storage:

Harrington, 1960

% Relative Humidity
+ Storage Temperature (F°)
= 100

Examples: 50% RH + 50 F° = 100

60% RH + 40 F° = 100
Not all humidity / temperature combinations will give good results for cold storage of seed:

Poor RH / Temp ratios:  
80% RH + 20 F° = 100  
10% RH + 90 F° = 100

Should strive for near equal values of each component.
Prior to committing seeds to cold storage, it should be remembered that if seed vitality has been diminished prior to entering cold storage, the benefit that otherwise would have been realized by good storage conditions will not be realized.

Any time in the life of a seed when its vigor / germination has been compromised, it cannot be regained, even through later optimum storage conditions.
Even if high energy costs do not allow for standard cold storage, ……….keep in mind the benefit that even less aggressive (Temp / RH) combinations can provide.

**cool** rooms, as opposed to **cold** rooms:

Even moderate reductions in temperature and humidity can offer benefit, ………. especially for species that tend to store well anyway.
In situations where cold room operational costs are prohibitive of year round use, in temperate areas, power use can be curtailed or ceased during winter months.

Should be cautious during such times that power is off, monitor seed moistures and RH more closely.
In practical terms, climate controlled storage can sometimes be used in combination with natural air storage, …… so long as the time period of natural air storage is consistent with at least moderately acceptable conditions with respect to temperature and relative humidity.
End
A PRESENTATION OF THE JACOBSEN HOLZ CORPORATION
Storing seed for maximized *germination*, *vigor* and *carryover life* present unique challenges to the seed producer.
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Providing customers with seed having “high” quality is more a process of quality *preservation* than quality *production*. 
Storing seed for maximized *germination*, *vigor* and *carryover life* present unique challenges to the seed producer.

Providing customers with seed having “high” quality is more a process of quality *preservation* than quality *production*.

Once the seed is harvested, this challenge begins in the *seed dryer*. The “result” of the *drying process* establishes the “*foundation*” for seed performance in storage both in bulk and bags.
Presentation Overview

- Moisture in the Seed
- Measurement of Seed Moisture
- Psychometrics as Pertaining to Seed “Drying”
MOISTURE IN THE SEED

- Moisture Internal to the seed is trying to reach an “equilibrium” with the moisture content of the surrounding atmosphere.
“Air” Pressure In A Balloon Attempts To Reach An “Air” Equilibrium With The Atmosphere
“Moisture” Pressure In A Kernel Of Corn Attempts To Reach A “Moisture” Equilibrium With The Surrounding Atmosphere
Moisture in the Seed

- Moisture internal to the seed is trying to reach an "equilibrium" with the moisture content of the surrounding air.
- Drying "Mechanism" = Vapor Pressure
MOISTURE IN THE SEED

- Moisture Internal to the seed is trying to reach an "equilibrium" with the moisture content of the surrounding air.

- Drying “Mechanism” = *Vapor Pressure*

- If the moisture “*pressure*” inside the seed is greater than the moisture “*pressure*” of the air, water leaves the seed and drying occurs.
Seed in kernel form is *fairly homogeneous* and moisture migration from inside the seeds to a “dryer” atmosphere can be considered *fairly uniform*. 
MOISTURE IN THE SEED

- Seed in kernel form is *fairly homogeneous* and moisture migration from inside the seeds to a “dryer” atmosphere can be considered *fairly uniform*.
- Seed kernels *still on the cob* is more *complex*. 
Moisture Held In The Cob Is Also Migrating To Achieve An Equilibrium With The Kernels And The Atmosphere
MOISTURE IN THE SEED

- Seed in kernel form is *fairly homogeneous* and moisture migration from inside the seeds to a "dryer" atmosphere can be considered *fairly uniform*.

- Seed kernels *still on the cob* is more *complex*.

- *Variations* in the ears of seed corn further *complicates* the process of *moisture migration* to a state of equilibrium further.
Seed in kernel form is *fairly homogeneous* and moisture migration from inside the seeds to a “dryer” atmosphere can be considered *fairly uniform*.

Seed kernels *still on the cob* is more *complex*.

*Variations* in the ears of seed corn further *complicates* the process of *moisture migration* to a state of equilibrium further.

This can be illustrated with *Kernel set*.
An Ear With Full Kernel Set Results in More Uniform Moisture Removal
If The Kernel Set Changes,
If The Kernel Set Changes, Moisture Migration and Seed Drying Characteristics
If The Kernel Set Changes, Moisture Migration and Seed Drying Characteristics Change Also
These And Other Factors Makes Seed Moisture Measurement While On The Ear Variable and Difficult!
More Accurate Moisture Measurement Requires Removing Seed From The Ear And Measuring As Kernels
PRESENTATION OVERVIEW

- Moisture In The Seed
- Measurement Of Seed Moisture
We talk about “measuring” seed moisture, however all commonly used techniques for seed moisture determination are actually a “prediction”.
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Moisture Measurement Techniques can be classified into two basic categories.

- Direct Methods
- Indirect Methods
Direct Methods – Are analysis techniques that utilize some form of moisture removal to "predict" moisture content.
**MEASUREMENT OF SEED MOISTURE**

- **Direct Methods** – Are analysis techniques that utilize some form of moisture removal to "predict" moisture content.
  - Oven Dry Down Method
  - Microwave Oven
  - Distillation - Brown–Duval
  - Various Moisture Removal Techniques
MEASUREMENT OF SEED MOISTURE

- **Indirect Methods** – Are analysis techniques that utilize other physical properties of the seed such as *dielectric value* or *resistance*. To "predict" moisture content.
**Indirect Methods** – Are analysis techniques that utilize other physical properties of the seed such as *dielectric value* or *resistance*. To *predict* moisture content.

- Seed Capacitance (dielectric value)
- Seed Resistance
- NIR – Near Infrared
- TDR – Time Domain Reflectometry
Capacitance Base Flow Through Shelled Seed Moisture Measurement
Captures a “Profile” of the seed moisture as the dyer bin is being shelled.
**PRESENTATION OVERVIEW**

- **Moisture In The Seed**
- **Measurement Of Seed Moisture**
- **Psychometrics As Pertaining To Seed “Drying”**
Psychometrics – The field of engineering concerned with the determination of physical and thermodynamic properties of gas-vapor mixtures
Psychometrics – The field of engineering concerned with the determination of physical and thermodynamic properties of gas-vapor mixtures

In the case of seed drying the atmosphere is the “gas” and moisture is the ”vapor”
Simplified Psychometric Chart

DRY BULB TEMPERATURE (F)
80
40
40
60
Wet Bulb (F)
50
50
60
70
70
40%
80 90 100 120
20%
80% 60%
90
.004
.016
.012
.008
HUMIDITY RATIO
(Lbv/Lba)
.028
.024
.020
.016
.012
.008
.004

Simplified Psychometric Chart
Dry Bulb Temperature Lines

Simplified Psychometric Chart
Simplified Psychometric Chart

Wet Bulb Temperature Lines

Dry Bulb Temperature (F)

Humidity Ratio (Lbv/Lba)

40 50 60 70 80 90 100 120

0.028
0.024
0.020
0.016
0.012
0.008
0.004

0.028
0.024
0.020
0.016
0.012
0.008
0.004

Simplified Psychometric Chart
Simplified Psychometric Chart

Relative Humidity Lines

Dry Bulb Temperature (F)

Humidity Ratio (Lvb/Lba)

Simplified Psychometric Chart
Simplified Psychometric Chart

Water Content (Humidity Ratio) Lines

DRY BULB TEMPERATURE (F)
80
40
40
60
Wet Bulb (F)
50
50
60
70
70
40%
80 90 100 120
20%
80% 60%
90
.004
.016
.012
.008
HUMIDITY RATIO (Lbv/Lba)
.028
.024
.020
.016
.012
.008
.004
HUMIDITY RATIO (Lbv/Lba)

Simplified Psychometric Chart
PSYCHOMETRICS AS PERTAINING TO “DRYING”

- Drying Process = **Evaporative Cooling**
  - “Energy” *from the air* is used to “evaporate” *moisture* from the seed.
A - 60F @ 60% RH
A - 60F @ 60% RH
B - 100F @ 20% RH
3 - AIR COOLED BY EVAPORATION

A - 60F @ 60% RH
B - 100F @ 20% RH
C - 67F @ 100% RH
Drying Process = Evaporative Cooling

- “Energy” from the air is used to “evaporate” moisture from the seed.
- Energy or “heat” is not lost. It changes heat “type” from sensible to latent heat.
EVAPORATIVE COOLING "ANALOGY"

100 F
20% RH

67 F
100% RH

WATER FROM SEED

WATER IN INLET AIR

WATER IN EXHAUST AIR
EVAPORATIVE COOLING “PARALLEL”

- Wet Bulb (F)
- Dry Bulb Temperature (F)
- Humidity Ratio (Lb/Lba)

Graph showing the relationship between wet bulb temperature, dry bulb temperature, and humidity ratio.
Example Of Psychometrics Applied To The Seed Drying Process
Adding Heat To Ambient Air

Ambient Air:
60F @ 60%RH

Add:
20F

Result:
80F @ 32%RH

Ambient Air:
60F @ 60%RH

Add:
20F

Result:
80F @ 32%RH
Increased Water Capacity To Heated Air

Moisture Capacity (Lbs Water / Lbs Air)

60F Air = .011
80F Air = .022

Increased Water Capacity To Heated Air
Increased Water Capacity To Heated Air

For a 20F Rise From 60F To 80F The Capacity Of The Air To Hold Water DOUBLES:

60F Air = .011 Lbs. Water / Lbs. Air
80F Air = .022 Lbs. Water / Lbs. Air

Net Gain = .011 Lbs. Water / Lbs. Air
Increased Water Capacity Is Non-Linear

Moisture Capacity (Lbs Water / Lbs Air)

- 60°F Air = 0.011
- 80°F Air = 0.022
- 90°F Air = 0.032

Dry Bulb Temperature (F)
- 40°F
- 50°F
- 60°F
- 70°F
- 80°F
- 90°F

Wet Bulb (F)
- 40°F
- 50°F
- 60°F
- 70°F

Humidity Ratio (Lbs Water / Lbs Air)
- 0.004
- 0.008
- 0.012
- 0.016
- 0.020
- 0.024
- 0.028
- 0.032
Increased *Water Capacity To Heated Air*

For a **10F** Rise From **80F To 90F**  
The Capacity Of The Air To Hold Water **INCREASES BY NEARLY THE SAME AMOUNT:**

80F Air = **0.022** Lbs. Water / Lbs. Air  
90F Air = **0.032** Lbs. Water / Lbs. Air

Net Gain = **0.010** Lbs. Water / Lbs. Air
Increased Water Capacity To Heated Air

For a 20F Rise From 60F To 80F
Net Gain = \textbf{.011 Lbs. Water / Lbs. Air}

For a 10F Rise From 80F To 90F
Net Gain = \textbf{.010 Lbs. Water / Lbs. Air}
PSYCHOMETERS – WET & DRY BULBS

- Fan
- Wet Bulb (with wick)
- Dry Bulb
PSYCHROMETERS – ELECTRONIC
End Of Presentation
Thank You!
Pre-Cleaning
What is pre-cleaning?

The removal of inert matter from desirable seed prior to drying, storage, and conventional seed cleaning.
Methods of pre-cleaning:

- Aspiration
- Screening
Advantages of pre-cleaning:

- Increase aeration
- Increase bulk storage space
- Increase capacity of conventional cleaning line
- Increase seed quality
- Increase cleanliness of processing facility
- Decrease down-time
- Decrease contamination
- Decrease drying costs
Pre-Cleaning

**LMC Aspirator**

**EXPANSION CHAMBER**
Allows the reject product to drop out of the air stream. Liftings are conveniently discharged for inspection and, if needed, adjustment to the air stream can be made.

**AIR COLUMN**
Allows the product to be lifted and stratified for a more precise separation.

**OUTFALL HOPPER & AIRLOCK**
Allows the liftings to discharge with no air loss in the separation process.

**VARIABLE SPEED ROLL FEEDER (OPTIONAL)**
Enables the operator to easily and accurately adjust the flow to fit each individual situation.

**ADJUSTABLE IN-FEED**
Introduces the product into the air stream. The feed rate can be adjusted using a vibratory feeder option or slide pan option.
Pre-Cleaning

DUST / LIFTINGS FLOW

PRODUCT FLOW

TRASH / REJECT FLOW

AIR FLOW
Pre-Cleaning

#1 Accepts

#1 Rejects
Pre-Cleaning

#2 Accepts

#2 Rejects
Pre-Cleaning

#3 Accepts

#3 Rejects
Pre-Cleaning

Pre-clean Aspirator Rejects #1

Pre-clean Aspirator Rejects #2

Pre-clean Aspirator Rejects #3
## LMC Aspirator

### Model Specifications

<table>
<thead>
<tr>
<th>MODEL</th>
<th>AIRFLOW (cfm) at 2500 fpm</th>
<th>AIRFLOW (cfm) at 3000 fpm</th>
<th>AIRFLOW (cfm) at 3500 fpm</th>
<th>AIRFLOW (cfm) at 4000 fpm</th>
</tr>
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<td>1206</td>
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<td>17500</td>
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</table>
Pre-Cleaning

ASPIRATOR
The ADVENT utilizes the aspirator before the screening process to attain unmatched screening accuracy.

BALL TRAYS
Screen blockage is prevented by using 2” rubber balls. LMC developed a special system using round rods to impart the required action to the cleaning balls.

SCREENING
The product is evenly distributed between both decks.

The first screening is normally a sifting process to remove the smaller reject particles and can be designed to any particular need. After the initial sifting, the product rides to the scalping area of the deck.

The decks can be equipped with multiple discharges to satisfy production specifications. All screens are mounted on tubular steel frames 24” long and are easily handled.

DECKS
ADVENTS are typically wider than the conventional cleaner and are manufactured in widths of 4, 5, 6, and 7 feet to provide this required spread for the desired capacity and length for precision.

If extra precision is required for a difficult separation, the decks can be designed with more length to attain the proper separation.
Pre-Cleaning

Advent Sifting

Advent Scalping
Pre-Cleaning

Receiving at the site
Pre-Cleaning

Twin 1206D Aspirators
Pre-Cleaning

Twin 846D's
Pre-Cleaning

Twin 846D's
Seed Damage
Methods to reduce seed damage:

- Minimize spout angles
- Reduce product fall in transition areas
- Utilize cushion boxes for direction changes in spouting
- Minimize the use of screw conveyors
- Minimize the use of drag conveyors after pre-cleaning
- Install bean ladders in bins
- Transfer seed with vibratory conveyors wherever possible
- Elevate seed with LMC Easy Dump Elevators
Seed Damage

DISCHARGE SPOUT OPTIONS

Reversible Discharge Spout
By simply removing the bolts from the spout and cover plate, the discharge direction can be altered without breaking the chain assembly.

Bi-directional Discharge Spout
Product can be simultaneously discharged from both sides of the elevator should separate bins or machines need to be fed at the same time.

Switch Valve Discharge Spout
Products can be discharged from either side by a manual or pneumatic valve.

BOLTED ASSEMBLY

The legging can be shipped broken down, thereby reducing freight costs.

POSITIVE CLEAN-OUT BOOT

The boot is tapered to a drawer action assembly which, when opened, completely empties the boot. Built-in boot clearance above the floor enables quicker, more effective clean-outs and maintains proper sanitation.

LADDERS, CAGES, REST AND SERVICE PLATFORMS

OSHA compliant ladders, cages, rest and service platforms are all optional features that can be included in your specific design.
Seed Damage
# LMC Easy Dump Elevator

## Model Specifications

<table>
<thead>
<tr>
<th>MODEL</th>
<th>BUCKET SIZE</th>
<th>CUBIC FT/HR</th>
<th>CAPACITY at 35 lbs/cubic ft (85% fill)</th>
<th>CAPACITY at 48 lbs/cubic ft (85% fill)</th>
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<tr>
<td>3508</td>
<td>5” x 7”</td>
<td>485</td>
<td>16,030 lbs/hr</td>
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<td>6” x 9”</td>
<td>800</td>
<td>28,000 lbs/hr</td>
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<tr>
<td>3518</td>
<td>6” x 12”</td>
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<td>35,980 lbs/hr</td>
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<td>3530</td>
<td>6” x 18”</td>
<td>1,714</td>
<td>59,990 lbs/hr</td>
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<td>3540</td>
<td>6” x 24”</td>
<td>2,285</td>
<td>79,975 lbs/hr</td>
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<td>3560</td>
<td>10” x 24”</td>
<td>3,428</td>
<td>119,980 lbs/hr</td>
<td>164,544 lbs/hr</td>
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</table>
Seed Damage

Standard Single Pan Vibratory Conveyor

Standard Single Pan Vibratory Conveyor With Optional Screening
Thank you for your time!

Pre-Cleaning & Seed Damage
The essence of the seed industry is the ability to identify varieties or hybrids with high yield that have the traits and characteristics desired by the Farmer or Food Processor and to deliver them at a fair price (profit).
Overall Purpose

- The purpose of seed testing is to mitigate risk.
- Quality assurance
- Quality control
- Reduce complaints
- Protect the company
- Protect our reputation
- Protect customers and consumers
Testing Plans and Sample Plans

• How do you know what to test for?

• How do you know what is needed for sampling?

• These two are inseparably connected.

• It is critical that they match up in their purposes.
What do we test for?

- Federal Seed Act and State Seed Laws
  - Label Requirements
- Certification Requirements (including Import / Export Requirements)
  - Genetic / Varietal Purity
- Contractual Obligations
  - Trait Purity
- Other Agency Requirements
  - EPA
- Marketing Claims
- Inventory Control
- Quality Assurance / Control
So, what’s the big deal around sampling?

- Definition of a seed lot:

  Quantity of seed for which the indicators of quality are uniform and homogenous.

  In other words, all the defective seeds are equally distributed throughout the entire seed lot.
I really should have paid more attention in High School Physics! and What was that about Statistics?

• Seeds are solids that only behave like fluids when they are moved.
• Defective seeds do not diffuse throughout the entire seed lot.

• Samples must be representative of the seed lot.

• Random sampling is one way we accomplish that.

• Automatic periodic sampling is another way we achieve a representative sample.

• Sampling size v. Sampling frequency
Standard sampling and testing

• Assumptions
  - The seed lot is uniform
  - The seed lot is homogenous

• Tests to be performed: Germination, Purity, Noxious, Genetic Purity

• Samples are taken randomly or periodically from the seed lot.
• Subsamples are taken randomly and tests are performed.
AASCO Handbook on Seed Sampling

• Published by the Associations of American Seed Control Officials

• Topics:
  ▪ Procedures for sampling seed with a trier
  ▪ Selecting and using a trier
  ▪ Procedures for sampling seed without a trier
  ▪ Special sampling considerations
  ▪ Preparation of the composite sample
  ▪ Quality assurance
  ▪ Safety and health
  ▪ Sampling mini-bulk containers
  ▪ Recommended sample size
  ▪ Equipment and supplies
# Sample frequency examples

<table>
<thead>
<tr>
<th>Lot Size</th>
<th>10</th>
<th>15</th>
<th>30</th>
<th>100</th>
<th>200</th>
<th>300</th>
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<tr>
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<td>6</td>
<td>7</td>
<td>8</td>
<td>15</td>
<td>25</td>
<td>30</td>
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</table>
Non-standard sampling

• Blends
  ▪ Two or more seed kinds with similar physical properties
    – Blended refuge products
  ▪ Two or more seed kinds with dissimilar physical properties
    – Turf grass
    – Cover crop blends

• Sampling for prohibited items
  ▪ GMO tests
  ▪ Noxious weed exams when a problem is known to exist
In conclusion

• Seed Sampling and Testing are complex issues.

• Schemes can be defined to accomplish sampling and testing to meet our needs

• Based on:
  ▪ Knowing what the testing requirements are,
  ▪ Understanding the challenges of sampling
Seed Drying Goals

Basic Seed Corn Dryer Types

Effects Of Temperature, Humidity and Airflow

“Seed” Factors That Effect Drying

Drying Concepts
What Are The Primary Goals Of Seed Corn Drying?
SEED DRYING GOALS

- Maintaining Seed Quality
Seed quality can only be maintained, not improved.
Seed quality can only be maintained, not improved

The Drying Process has the greatest potential in seed conditioning to reduce germination, vigor and carryover life
Seed quality can only be maintained, not improved.

The Drying Process has the greatest potential in seed conditioning to reduce germination, vigor and carryover life.

Seed quality is difficult (expensive) to measure as it comes out of dryer.
Seed quality can only be maintained, not improved

The Drying Process has the greatest potential in seed conditioning to reduce germination, vigor and carryover life

Seed quality is difficult (expensive) to measure as it comes out of dryer

Seed Damage Is Permanent And Cannot Be Reversed
The Seed Dryer is often the "Bottleneck" of the production process. It dictates plant intake operations of field harvest, sorting and shelling.
2 - MAXIMIZED DRYER THROUGHPUT

- Minimized *Drying Time*
- Maximized *Dryer Efficiency*
Maximized Dryer Efficiency

Seed Dryer Efficiency is commonly considered to be the total time that the bin is drying (air is on) verses the time the seed is in the dryer.
2 - MAXIMIZED DRYER THROUGHPUT

- Minimized *Drying Time*
- Maximized *Dryer Efficiency*
- Efficiency = Total Drying Time (on air) vs, Total Bin Time
3 - DRYING PREDICTABILITY

- Ability to *estimate* current *dry rate* and *moisture* content
- Ability to *predict when* a bin of *seed will be dry*
There are many "correct" methods for drying seed corn.
SEED DRYING GOALS

Faster / More Risky
SEED DRYING GOALS

Moderate / Less Risky
PRESENTATION OVERVIEW

- Seed Drying **Goals**
- Basic Seed Corn **Dryer Types**
BASIC SEED CORN DRYER TYPES

- DPR – Double Pass Reversing
- SPR – Single Pass Reversing
- SP – Single Pass
In the **DPR Dryer** An Upper & Lower Tunnel That Are Common To The Bins Are Pressurized Via 2 – 6 Large Fan-Burner Systems Located At Each End Of the Upper Tunnel.
DPR – Double Pass Reversing

Laminar Air Flow

Drying Front
In the DPR Dryer, The Heated Air Is Passed Though a Seed Pile Twice. First Through A Bin on Down Air And Then Through A Bin On Up Air. Hence the Term “Double Pass”
1. Heated Air Pressurizes the Upper Tunnel And Is Directed Into Bins on Down Air Via A System Of Air Control Doors
2. The Heated Air Passes Down Through The Seed Pile And Exhausts Into The Lower Tunnel. The Seed Exchanges Moisture For Heat As It Passes Through The Seed Pile To Pressurize the Lower Tunnel With Lower Temperature Air.
3. The Lower Tunnel Air, “Tempered” With Moisture Is Directed Into Bins on **Up Air** Via A System Of Air Control Doors And Exhausted Into The Atmosphere.
“Reversing” Refers To The Ability Of The Dryer To Control The Direction Of Air Flow Though The Seed Pile
A Typical Commercial DPR Dryer

- 24 Bins – 16’ X 12’ X 10’ of Seed Depth
- 1000 Shelled Bushel Capacity
- 4 Fans-Burner Systems
- Total Heating Capacity Of 48MBtu/Hr. Or 2MBtu/Hr. Per bin
DPR – Pros & Cons

- DPR Advantages
  + Second Pass air “tempered” with moisture from the First Pass Which enables lower dry rates for Up Air pass and potentially less damage
  + Reduced moisture gradient
  + Increased energy efficiency
  + Less total cost of ownership
DPR – Pros & Cons

- DPR Disadvantages
  - Complexity Of Operation
    - Maintaining lower tunnel temperature
    - Maintaining Dryer Balance
  - Dryer setup for a single hybrid dry-rate “type”
In the **Single Pass Dryer**, the heated air is passed though a seed pile only **Once**. Typically there is **One Fan-Burner System Per Bin**.
“Reversing” Refers To The Ability Of The Dryer To Control The *Direction Of Air Flow* Though The Seed Pile
SPR – Single Pass Reversing

- A Typical Commercial SPR Dryer would likely have individual Fan-Burner Systems for each bin each with a Capacity of around 1 - 2MBtu/Hr. Per bin
**SPR – Single Pass Reversing**

- **Fan-Burner System**
- **Single Pass Reversing Dryer**
  - Setup For **Down Air** Pass
- **Seed Pile**
- **Outlet Air**
SPR – Single Pass Reversing

Single Pass Reversing Dryer
Setup For Up Air Pass
SPR – Pros & Cons

- SPR Advantages
  - Reduced moisture gradient
  - Simplicity of Operation
  - Can Accommodate Multiple Hybrid Dry-Rate “Types“
SPR – Pros & Cons

- SPR Disadvantages
  - Dry rates limited to ambient conditions.
  - Decreased energy efficiency
  - Greater Total Cost Of Ownership
    - Capital Costs / Bu – individual fans and burners
    - Maintenance Cost / Bu – individual fans and burners
In the **Single Pass Dryer**, The Heated Air Is Passed Though a Seed Pile Only *Once*. Typically There Is **One Fan-Burner System Per Bin**.
SP – Single Pass

Fan-Burner System

Outlet Air

Seed Pile

Single Pass Dryer
Up Air Pass Only
SP – Pros & Cons

- SP Advantages
  - Less total cost of ownership
  - Simplicity of Operation
  - Can Accommodate Multiple Hybrid Dry-Rate “Types“
SP – Pros & Cons

- SP Disadvantages
  - Dry rates limited to ambient conditions.
  - Increased moisture gradient
  - Decreased energy efficiency
Seed Drying Goals

Basic Seed Corn Dryer Types

Effects Of Temperature, Humidity and Airflow
“Atmospheric” Factors That Affect Dry Rate

1. Moisture Content - %RH
“Atmospheric” Factors That Affect Dry Rate

1. Moisture Content - %RH
2. Temperature
TEMPERATURE, HUMIDITY AND AIRFLOW

“Atmospheric” Factors That Affect Dry Rate

1. Moisture Content - %RH
2. Temperature
3. Airflow
Air Moisture Is Not Controllable By Operator
- **Air Moisture** *Is Not Controllable By Operator*
- **Temperature** *ALWAYS Increases Dry Rate at Geometric Rate*
Adding Heat To Ambient Air

Ambient Air:
60F @ 60%RH

Add:
20F

Result:
80F @ 32%RH
Increased Water Capacity To Heated Air

Moisture Capacity (Lbs Water / Lbs Air)

60F Air = .011
80F Air = .022

Increased Water Capacity To Heated Air
Increased Water Capacity To Heated Air

For a 20F Rise From 60F To 80F The Capacity Of The Air To Hold Water DOUBLES:

60F Air = 0.011 Lbs. Water / Lbs. Air
80F Air = 0.022 Lbs. Water / Lbs. Air

Net Gain = 0.011 Lbs. Water / Lbs. Air
Increased Water Capacity Is Non-Linear

Moisture Capacity (Lbs Water / Lbs Air)

- 60°F Air = .011
- 80°F Air = .022
- 90°F Air = .032
Increased Water Capacity To Heated Air

For a 10F Rise From 80F To 90F The Capacity Of The Air To Hold Water INCREASES BY NEARLY THE SAME AMOUNT:

80F Air = .022 Lbs. Water / Lbs. Air
90F Air = .032 Lbs. Water / Lbs. Air

Net Gain = .010 Lbs. Water / Lbs. Air
Increased Water Capacity To Heated Air

For a 20F Rise From 60F To 80F
Net Gain = \textbf{0.011 Lbs. Water / Lbs. Air}

For a 10F Rise From 80F To 90F
Net Gain = \textbf{0.010 Lbs. Water / Lbs. Air}
- **Air Moisture** *Is Not Controllable By Operator*
- **Temperature** *ALWAYS Increases Dry Rate at Geometric Rate*
- **Air Flow** *Has Limited Ability To Increase Dry Rate*
- **Air Moisture** is *not controllable by operator*
- **Temperature** *always increases dry rate at geometric rate*
- **Air Flow** has *limited ability to increase dry rate*
- **Air Flow** reaches a “*point of diminishing return*”
- **Air Moisture** is *not controllable* by operator.
- **Temperature** *always* increases **Dry Rate** at geometric rate.
- **Air Flow** has *limited ability* to increase **Dry Rate**.
- **Air Flow** reaches a “**Point Of Diminishing Return**”.
- **Excessive Air Flow** can potentially compromise seed quality.
Excessive Air Flow Can Promote Seed Damage

Potential For Seed Quality Compromise From Excessive Air Flow On Up Air Pass
The “Dynamic” Dry Rate

Actual vs. Average Moisture Removal

- 2.0 Hrs/Pt.
- 3.0 Hrs/Pt.
- 3.5 Hrs/Pt.
- 3.0 Hrs/Pt.
- 3.5 Hrs/Pt.

Starting Mst.  Final Sample Mst.  Shell Mst.

Hours: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90
Moisture Content (%): 45, 40, 35, 30, 25, 20, 15, 12, 10, 5, 0
Seed Drying *Goals*

Basic Seed Corn *Dryer Types*

*Effects Of Temperature, Humidity and Airflow*

“Seed” *Factors* That Effect Drying
“Seed” Factors That Affect Dry Rate

1. Seed Physiology – Seed Coat Permeability
2. Seed Moisture Content
3. Seed Temperature
4. Seed Set - Pollination
Seed Drying **Goals**

Basic Seed Corn **Dryer Types**

**Effects** Of **Temperature, Humidity** and **Airflow**

**“Seed” Factors** That Affect Dry Rate

Drying **Concepts**
Drying Concepts

- Airflow the "Unseen" Factor
- The "Drying Front" Phenomenon
- The "Dynamic" Dry Rate
- The Importance Of Bin Loading
AIRFLOW THE “UNSEEN” FACTOR

- Pressure is only an “Indicator” of Airflow
AIRFLOW THE “UNSEEN” FACTOR

- Pressure is **only** an “Indicator” of Airflow
- It is **Airflow** that Effects Dry Rate
AIRFLOW THE “UNSEEN” FACTOR

- Pressure is **only** an “Indicator” of Airflow
- It is **Airflow** that Effects Dry Rate
- Airflow **Velocity** and **Uniformity** are both Important to Dry Rate and Predictability
- How a Bin is Loaded Greatly Affects Airflow **Velocity** and **Uniformity**.
DRYER MANAGEMENT CONCEPTS

- Airflow the “Unseen” Factor
- The “Drying Front” Phenomenon
A – Drying Front Level Soon After Drying Begins *(DBT = WBT)*
B – Drying Front Level After Several Hours Of Drying *(DBT = WBT)*
C – Drying Front Level Reaches The Top Of The Seed Pile *(DBT > WBT)*
Bin Graph Illustrating Drying Front

C - Dry Bulb > Wet Bulb
B - Dry Bulb ≈ Wet Bulb
A - Dry Bulb ≈ Wet Bulb
DRYER MANAGEMENT CONCEPTS

- Airflow the “Unseen” Factor
- The “Drying Front” Phenomenon
- The “Dynamic” Dry Rate
The “Dynamic” Dry Rate

Actual vs. Average Moisture Removal

- 2.0 Hrs/Pt.
- 3.0 Hrs/Pt.
- 3.0 Hrs/Pt.
- 3.5 Hrs/Pt.
- 3.0 Hrs/Pt.
- 3.5 Hrs/Pt.
- 4.0 Hrs/Pt.

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45

Hours

Moisture Content (%)
DRYER MANAGEMENT CONCEPTS

- Airflow the “Unseen” Factor
- The “Drying Front” Phenomenon
- The “Dynamic” Dry Rate
- The Importance Of Bin Loading
THE IMPORTANCE OF BIN LOADING

- How a Bin is Loaded Greatly Affects Airflow Velocity and Uniformity.
THE IMPORTANCE OF BIN LOADING

- Bin Loading is Largely Under the Operators Control
THE IMPORTANCE OF BIN LOADING

- How the Bin is Loaded **Cannot Easily be Corrected** if not done Well.
• Bin Section A: **Uniform Depth** = **Uniform Drying** = Uniform Temperature Delta
• Bin Section B: **Uniform Depth** = **Uniform Drying** = Uniform Temperature Delta
• Bin Section C: **Uniform Depth** = **Uniform drying** = Uniform Temperature Delta
Bin Graph Illustrating *Extended* Drying Time

**Non-Uniform Fill Depth**

- **Outlet Air Briefly Saturated**
- **Temperature Delta Remains Constant**
- **Majority Of Air Flow Is Passing Through Dryer Seed**
- **Extended Drying Time**

**Temperature vs. Hours**

- **Upper Temp**
- **Lower Temp**
- **Wet Bulb**
Bin Zone *Airflow & Temperature Variations With Adverse Seed Pile Conditions*

- Bin Zone A: **Shallow Depth** = Increased Air Flow
- Bin Zone B: **Seed Pocket** = Decreased Air Flow
- Bin Zone C: **Increased Depth** = Decreased Air Flow
End Of Presentation
Thank You!
There are many “correct” methods for drying seed corn.
SEED DRYING GOALS

Faster / More Risky
SEED DRYING GOALS
End Of Presentation
Thank You!
Bulk Storage Systems

David Stimpson, Seed Regulatory Compliance Leader, Dow AgroSciences

Seed Technology Short Course
Aug. 4-5, 2015
Mississippi State University
What is the value of this Seed Technology Short Course?

- 3 D Photography
- Multi-dimensional vision
- A new view of reality
- New “vision” leads to new thinking!
- Look for new ways of doing things.
The essence of the seed industry is the ability to identify varieties or hybrids with high yield that have the traits and characteristics desired by the Farmer or Food Processor and to deliver them at a fair price (profit).
The Essence of the Seed Industry

• What does this mean?

- Maintain Genetic / Varietal Purity
- Maintain Germinative Quality
Objectives of Bulk Storage

- Interim Holding – usually waiting for the conditioning schedule.
- Preserving Quality and Product Integrity

- Also, Bulk Storage may provide holding from which to load trucks destined for large acreage customers (North Central soybeans, KS wheat)
If I am a Quality Assurance Auditor, what do I look for in Bulk Storage?

- Loading Control
  - The highest risk of accidental mixture is whenever a container is opened.
- Unloading Control
  - The highest risk of accidental mixture is whenever a container is opened.
- Ease of Cleanout
- Let-down ladders to minimize mechanical damage
  - What happens when seed drops ~100 ft?
- Aeration – what are the most important factors affecting seed quality in storage?
- Temperature monitoring
- Predation control – insects, vermin, disease.
- Security
If I am an Improvement Leader, what am I looking for in Bulk Storage?

- Automation
- Automated Control
- Pre-cleaning
  - Aspiration to remove trash
  - What about upgrading seed lots for germination? For genetic purity?
- Easier sampling.
- Is there a way to stir seed without causing damage?
- Can we facilitate blending from the bulk bin?
  - Precision and accuracy are the critical pieces.
  - Accurate blending can only be done by seed count.
- Flexible enough to accommodate different sized seed lots
Finally
What about cost?

• There always has to be balance between the 3 factors:

  ❖ Quality

  ❖ Efficiency

  ❖ Cost
Presented by:

Steven A. Waechter
Sukup Manufacturing Co.

Seed Tech 2015
Bost Extension Center
Mississippi State University
Starkville, MS
Air and Airflow

- Properties
- Qualities
- Their uses
Air and Airflow

• Properties
  – Inert
  – Has no energy of its own
  – Requires atmospheric event or mechanical means to move

– Flexible – it can be:
  • Compressed
  • Expanded
  • Manipulated / controlled
  • Pushed
  • pulled
Air and Airflow

• Qualities
  – Air temperature
    • Key in cooling and warming grain
    • Cooler grain stores easier and longer than warm grain
    • Grain temperature is relative to climate
      – Cool grain in a warm climate can be a problem
      – Warm grain in a cool climate can be a problem

Grain stored in warmer climates will need to be dried to a lower moisture content than grain stored in cooler climates
Air and Airflow

• Qualities
  – Air temperature
    • Grain temperature must be kept within 10°-15° of the average ambient temperature
      – Greater differential in temperature increases the risk of condensation
Air and Airflow

• Qualities
  – Moisture Content
    • 90% RH air is air that is 90% of saturation
    • 45% RH air has capacity to absorb 55% more moisture before it is saturated
Air and Airflow

- Grain is **hygroscopic** – it will take on and retain moisture based on the relative humidity in surrounding air.
Air and Airflow

- Air Temperature and Moisture Content, Now What?
  - Air has to be moving
  - Properly selected fan for the application
Static Pressure

- What is it?
- What causes it?
- Overcoming it
Static Pressure

- **What is it?**
  - Result of resistance to flow
    - Equal in all directions
    - Can be positive or negative
    - Independent of air velocity
  - Can be measured with a manometer
    - digital
    - analog (U-tube)
Static Pressure

• What is it?
  – Result of resistance to Air flow
    • Equal in all directions
    • Can be positive or negative
    • Independent of air velocity
  – Can be measured with a manometer
    • digital
    • analog (U-tube)
Static Pressure

• What causes it?
  • Grain mass
  • Components of an air system
  • Excessive airflow can cause static pressure

• Static Pressure must be factored into the airflow equation
Static Pressure

- Digital Manometer
4" Of Water Column (Static Pressure)

From Bin Plenum

"U" Tube Manometer

From Bin Plenum

"U" Tube Manometer
Static Pressure

• Overcoming it
  – Selecting the proper type of fan or fans
  – Reducing grain depth
  – Stirring the grain
Differences in airflow properties (based on crop)

- Seed or kernel size
- Density
- Grain depth
Differences in airflow properties (based on crop)

• Seed or kernel size
  – Seed symmetry and size play a huge role in airflow characteristics
    • A kernel of corn has an irregular shape
    • More spherical seeds (ex. soybeans or canola) are more aerodynamic
• Density
  – The smaller the seed size the higher the density and the higher resistance
  • There is less room for air to flow between the kernels
  – Certain seeds tend to pack tighter or “stack” reducing airflow
• **Grain depth**

  – May be the only way to ultimately control static pressure and airflow capacity
Aeration vs Drying

- Airflow requirements for Aeration
- Airflow requirements for Drying
Aeration vs Drying

• Airflow requirements for Aeration
  – Aeration is the process used to manage the condition of grain in storage after it has been dried
    • used to change the grain temperature as required in seasonal climatic changes
    • Used to upset or counter any convection air currents
Aeration vs Drying

- Airflow requirements for Aeration
  - Can be done with a positive or negative pressure system
    - Positive airflow is best – moisture being removed exits out the top
    - Negative airflow tends to deposit moisture condensation at the bottom of grain mass
Aeration vs Drying

• Airflow requirements for Aeration
  – Requirements range from 1/20\(^{th}\)-1/7\(^{th}\) CFM/Bu.
  – 1/10\(^{th}\) CFM/BU. is considered normal
Aeration vs Drying

- Airflow requirements for Drying
  - Drying airflow rates are considerably greater
  - Minimum airflow rate 1 CFM/Bu
  - Moisture at the surface is absorbed by the air and carried away
Aeration vs Drying

• Airflow requirements for Drying
  – Air alone cannot complete the drying process fast enough to prevent spoiling
  – Heat needs to be used
    • 20° heat rise – 90% RH air reduces to 45% RH air
    • Every 20° heat rise cuts humidity in half
Air and Moisture Movement in Storage

• Convection Currents
• Causes of Convection Currents
• How to Control these Currents
Air and Moisture Movement in Storage

• Convection Currents
  – Occur naturally in storage structures
  – Can have disastrous consequences
Air and Moisture Movement in Storage

• Causes of Convection Currents
  – Major cause is temperature differentials
    • Occur when air on the outside of the structure contrasts with air and/or grain temperature on the inside.
    • Cold air settles, warm air rises.
    • Most common evidence is crusting at the top center of the grain mass
Air and Moisture Movement in Storage

• How to Control these Currents
  – Move grain from one structure to another
    • Labor intensive
    • Requires empty storage structure
    • Damaging to the grain
Air and Moisture Movement in Storage

• How to Control these Currents
  – Various types of fans & proper grain management practices
Questions?
Thank You!
Stored Grain Pest Management

Kathy Flanders
Insects That Feed on Whole Kernels

5. Lesser grain borer

6. Rice weevil, *Sitophilus oryzae*

10. Angoumois grain moth, *Pylophora*
X-rays of Rice Weevil Infested Grain

Slide courtesy M. Toews, Univ. GA
Insects That Feed on Broken Kernels or Flour

7. Indian-meal moth

3. Red flour beetle

2. Saw-toothed grain beetle

9. Flat grain beetle
Development of stored product insects depends on

- Temperature
- Moisture
- Initial pest pressure
- Time

Does this sound familiar?
Insects are cold-blooded

- Generation time depends on temperature and moisture
- 30 days is a good rule of thumb
Reproduction of red flour beetles (25 pairs) in clean wheat as affected by temperature and grain moisture, indicated by number of progeny after 5 months (Cotton et al, 1960)
## Recommended Moisture Content

<table>
<thead>
<tr>
<th></th>
<th>6 months</th>
<th>6-12 months</th>
<th>&gt; 1 year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn &amp; sorghum</td>
<td>14%</td>
<td>13%</td>
<td>12%</td>
</tr>
<tr>
<td>Soybeans</td>
<td>13%</td>
<td>12%</td>
<td>11%</td>
</tr>
<tr>
<td>Small Grains</td>
<td>12%</td>
<td>11%</td>
<td>10%</td>
</tr>
<tr>
<td>Edible beans</td>
<td>14%</td>
<td>12%</td>
<td>10%</td>
</tr>
</tbody>
</table>
Time and Initial Pest Pressure

No. per 15 trap days

1-Jun    1-Jul    31-Jul    30-Aug    29-Sep

0        0        0        0         450
Development of insects (and fungi) depends on

- Temperature
- Moisture
- Initial pest pressure
- Time
Keep it **Clean** and Dry

Keep it **Cool** & Dry

Check it often
Keep it Dry…..
Keep it Clean

Reduce the number of insects you are starting with
Where do insects come from?

- The field (maize weevil)
- Surrounding woods (lesser gb)
- HOME GROWN IN THE STORAGE FACILITY
Keep it Clean

• Clean harvesting equipment
• Set combine to blow out bad kernels – e.g. head scab
• Timely harvest – esp. corn
Keep it Clean

• Segregate the field edges?

• Stinkbugs and weevils like field edges, stressed plants on edges lead to high aflatoxin - UGA

[Image of a field with plants and animals]
Sanitation

Some stored grain beetles can live for years as adults.
Keep it Clean

- Remove weeds and clutter from outside of bin
- Clean out old grain and debris in the bin
Keep it Clean

• Spray bins with empty bin treatment – inside and outside
• Apply a protectant (apply an insecticide as the commodity is loaded)
Empty bin treatments protect against insects in cracks and crevices, as well as those under the floor.
# Maintaining Quality of Stored Grain

<table>
<thead>
<tr>
<th><strong>Videos and Podcasts</strong></th>
<th><strong>Publications and Other Information</strong></th>
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<tbody>
<tr>
<td>New September 2012! <a href="#">YouTube videos on Managing Stored Grain</a></td>
<td>IPM Recommendations for Stored Grain</td>
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<tr>
<td>Keep Watchful Eye on Stored Grain (blog post and podcasts, July 2010)</td>
<td>IPM Tactics for On-Farm Stored Grain</td>
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<tr>
<td>Stored Grain Needs Regular Monitoring (blog post and podcast, February 2010)</td>
<td>Grain Bin Hazards and Safety Considerations</td>
</tr>
<tr>
<td>Alabama Farmer Doug Trantham Discusses Importance of Pretreating Grain Bins (audio podcast, 2 minutes, 50 seconds)</td>
<td>Grain Dust Explosions</td>
</tr>
<tr>
<td>Scout Your Stored Grain for Insects, Kathy Flanders, Extension Entomologist (audio podcast, 8 minutes, 17 seconds)</td>
<td>Fumigating Agricultural Commodities with Phosphine</td>
</tr>
</tbody>
</table>
## Stored Grain Insecticides

<table>
<thead>
<tr>
<th>Product</th>
<th>Empty bin treatment</th>
<th>Grain Protectant</th>
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</thead>
<tbody>
<tr>
<td>Actellic</td>
<td>No!</td>
<td>Corn, sorghum</td>
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<tr>
<td>Storcide II</td>
<td>Small grain, sorghum</td>
<td>Small grain, sorghum</td>
</tr>
<tr>
<td>Diacon IGR</td>
<td>Most seeds</td>
<td>Most seeds</td>
</tr>
<tr>
<td>Diatomaceous earth</td>
<td>Diatomaceous earth</td>
<td>Diatomaceous earth</td>
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<tr>
<td>Centynal</td>
<td>Mix with IGR</td>
<td>Mix with IGR</td>
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<tr>
<td>Tempo SC Ultra</td>
<td>yes</td>
<td>No!</td>
</tr>
<tr>
<td>Nyguard</td>
<td>yes</td>
<td>No!</td>
</tr>
<tr>
<td>Seed treatment insecticides – imidacloprid, clothianidin, thiamethoxam</td>
<td>No</td>
<td>Yes follow label</td>
</tr>
</tbody>
</table>
Empty Bin Treatments

• Dust interferes with adherence of the spray and with the longevity
• Spray inside (wear respirator)
• and outside as far as you can reach
• Spray the pad – up to 10 ft or so away
Protectants

• Heat from dryer breaks down protectants – potential conflict of interest
• Rig a nozzle where the grain is the most cool
• Calibrate by determining the speed of the grain flow
• For example:
  
  \[ x \text{ oz. per 5 gal per 1000 bushels} \]
Protectants
Level peak and/or remove core of fine particles

And/or preclean your seed?
Avoid hotspots at all cost

Molds
Bacteria
Insects Too!
Keep it Cool and Dry

Make it hard for insects and molds to grow
Keep commodity <60 degrees
Aeration – redistribute moisture, cool grain to reduce insect growth
Automation Helps But You Don’t Have to Have It

Grain Storage Aeration Guidelines for the Southeast

Written by
Ronald T. Noyes, Ph.D., PE
Consulting Agricultural Engineer
Stillwater, Oklahoma 74074

For
Summer Grain Storage Workshops
Autaugaville, AL, August 21, 2001
Alexandria, AL, August 22, 2001

Organized by the Alabama Cooperative Extension System
Funding provided from Alabama Wheat and Feed Grains Check-Off Program
Check it Often

Be proactive. Don't let the insects sneak up on you.
Grain: Where to Sample

Top View of Truck

Grain Trier Sample

Top View of Grain Bin

Grain Trier or Probe Trap

Adapted from slide courtesy Paul Flinn, USDA
Warehouses
Last Resort - Fumigate

- Dangerous
- Time consuming
- Make a fumigation management plan
Fumigating Agricultural Commodities With Phosphine

Various ways are used to prevent insects from attacking stored products. Once insects get into a stored product, however, few practical solutions are available for getting rid of them. Small amounts of products can be frozen, or heated, to kill the insects. Large quantities need to be fumigated. This publication presents information about using phosphine fumigants to control insect infestations in stored agricultural commodities.

Phosphine fumigants are sold in solid form, either as aluminum phosphide or magnesium phosphide. This publication focuses on aluminum phosphide that is sold under various brand names including Phostoxin, Phosfume, and Weevilicide. Aluminum phosphide can be used to eliminate insect infestations in a variety of commodities, including animal feed and feed ingredients, corn, cottonseed, grass seed, millet, oats, peanuts, pecans, popcorn, rye, sorghum, soybeans, triticale, and wheat. They can also be used for a variety of processed foods as long as the residue dust does not come in direct contact with the product. They can be used on some nonfood commodities including straw and hay, cotton, feathers, tobacco, dried plants and flowers, and seeds. The fumigant label contains a complete list of commodities that can be fumigated. Phosphine fumigants can be used in a variety of structures including grain bins and silos, rail cars, warehouses, and flat storage structures.

When the solid fumigant is exposed to water vapor in the air, a chemical reaction occurs releasing phosphine gas (hydrogen phosphide) and heat:

\[
\text{Aluminum phosphide + Water = Phosphine gas + Aluminum hydroxide + heat} \]

\[
\text{AIP + H}_2\text{O} = \text{PH}_3 + \text{AI(OH)}_3 + \text{heat}
\]

The breakdown of the solid fumigant starts slowly, gradually accelerates, and then tapers off. When the chemical reaction has finished, all that is left is a non-hazardous gray powder consisting of aluminum hydroxide and other inert materials.

Phosphine gas is highly toxic, reactive, and potentially explosive. Because of the dangers associated with their use, phosphine fumigants are restricted-use pesticides that can be used only by trained and certified applicators in accordance with label instructions. Farmers who have a private applicator's license can apply phosphine fumigants on their farms.

An effective fumigation requires that the phosphine gas be held in the infested structure long enough to kill thetarget pests. After fumigation, the gas must be vented to the legal level for human exposure. These requirements are constant regardless of the structure involved; however, different types of structures may require different application procedures and safety considerations.

When you purchase a phosphine fumigant, be sure to ask for the applicator's manual, which is legally part of the fumigant label. The manual contains information needed to perform a safe, effective, and legal fumigation procedure. Read and follow all instructions on the container label and in the applicator's manual. Remember that the label, including the applicator's manual, is the law. This publication is not a substitute for the applicator's manual. It is meant to be an overview of the process of fumigation.

Frequently asked questions about aluminum phosphide:

Why should I read the applicator's manual?
- Your safety and the safety of others depend on it. Deaths have occurred from using the product improperly.
- Fumigations too often fail because the fumigant isn't applied correctly. This is a waste of time, money, and effort.
- The label is the law, and the applicator's manual is part of the label.

What is a fumigation management plan?

This is a written plan that summarizes all the steps that will be taken before, during, and after the fumigation. It makes sure that the fumigant is applied effectively and safely by forcing you to think about all the steps beforehand.

The applicator's manual explains what has to be in the plan; you must document who, what, when, where, how, and why. For example, who should be told about the fumigation because they might be accidentally exposed to phosphine gas during the fumigation, or who should be notified in case of emergency. Include the phone numbers of the nearest fire department, police department,
Flowing Grain Hazards

When a grain bin is unloaded, the grain flows downward from the top center creating a funnel effect where the conveyor transports the grain out of the bin. It takes less than 3 seconds for a person inside the bin to become helpless in flowing grain. The grain acts like quicksand and will pull a worker under the grain and cause suffocation. No one should enter a grain bin or gravity wagon when grain is present.

Crusted Grain Hazards

Stored grain can caké and form a crust leaving a hollow area below the crust. It can appear stable enough to walk on, but will usually break and instantly bury the worker in the hollow cavity that formed below the crust.

Figure 1

Entrapment can occur quickly as an unloading auger draws grain from the top center, forming a surface conical as the bin is emptied.

Safety Points

- Never enter a grain storage structure when it is being loaded or unloaded. All power conveying equipment, both automatic and manual, must be shut off, locked, and tagged to prevent unexpected operation.
- Always use a safety harness with a safety line and two observers during any grain bin entry.
- Install a permanent ladder on the inside of all grain bins for workers to use for emergency entry and exit.
- Secure all grain storage areas to prevent unauthorized entry.
- All external grain bin access ladders must be raised above the ground at a height that is inaccessible to children.
- Warn all workers, family members, and visitors about the dangers of flowing grain.
- Place warning decals on all bin entrances and gravity wagons.

Figure 2

Grain can form a hard crust that appears to be firm enough to walk on; however, the crust can break and instantly bury a worker in the hollow cavity that formed underneath the bridge.

Grain can also form large vertical columns against the bin wall, forming a V-shaped cavity in the center of the bin. Workers that dislodge the grain using a stick or other device may suddenly cause the wall to collapse, burying the worker.

Figure 3

If broken up from below, a steep wall of grain can break free and cause an avalanche that could bury a worker inside the bin.
Seed Storage Issues In Rice

By: Ernie Flint, Ph.D., CCA
Regional Extension Agronomy Specialist
Mississippi State University Extension Service
August 5, 2015
Seed quality is just like anything else, if you start with garbage you will end up with garbage.

When quality is poor in the beginning it can’t be improved in storage.

The purposes of this shortcourse is to help participants improve the seed that go into the system and that come out of it by improving the practices that take place between these points.
What is deterioration?

Seed deterioration can be defined as alterations occurring with time that increase the seed’s exposure to stresses that reduce the ability of the seed to perform its function of producing new plants. Seed deterioration causes loss of quality with time.

It is a natural process that involves cellular, physiological, biochemical, and physical changes in seeds. These changes reduce viability and ultimately lead to death of the seed.
Relative Storability of Seed by Species:

Category 1 – 50% of the seed are expected to germinated after 1 to 2 years of storage.  
Category 2 – 50% of the seed are expected to germinate after 3 to 5 years of storage.  
Category 3 – 50% of the seed are expected to germinate after 5 or more years of storage

<table>
<thead>
<tr>
<th>Category 1</th>
<th>Category 2</th>
<th>Category 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean</td>
<td>Rice</td>
<td>Bentgrass</td>
</tr>
<tr>
<td>Cotton</td>
<td>Wheat</td>
<td>Ryegrass</td>
</tr>
<tr>
<td>Peanut</td>
<td>Oats</td>
<td>Buffalograss</td>
</tr>
<tr>
<td>Cowpea</td>
<td>Corn</td>
<td>Tomato</td>
</tr>
</tbody>
</table>

While this kind of classification is very arbitrary it does suggest that some types of seed are more easily stored for future use than others. Fortunately rice is a type of seed that normally stores well under good conditions.
The longevity of a seed lot is the length of time the seed remain viable after reaching physiological maturity. For seed storage purposes, longevity is used synonymously with storability. To preserve initial seed quality, seeds must be properly stored between the time of harvest and the planting of a subsequent crop. Bulk storage is the period from harvest through packaging and includes conditioning. Packaged storage is the period between packaging and distribution; and distribution storage covers the period up to the time of sale to farmers, including time at wholesalers and retail outlets. (Delouche, 1968)

There is also a variable period of time when seed are stored on a farm while waiting for the day of planting. This period of time may be significant in some cases since very few farms have facilities suitable for maintaining a good storage environment for their planting seed. (Flint, 2015)
All of these are important but the primary factors are:

**Moisture**

and

**Heat**
Apparent signs of seed deterioration:
The Peak of Seed Quality is at Physiological Maturity. After this point deterioration begins. It’s our job to slow down this process of quality decline.
Classic comparison of relationship between germination and vigor of seed.
Deterioration of rice:

Islam, Delouche, and Baskin, MSU Seed Technology Lab., 1973
COMPARISON OF METHODS FOR EVALUATING
DETERIORATION IN RICE SEED

A. J. M. Azizul Islam, James C. Delouche and Charles C. Baskin

Mississippi State University
Mississippi State, Mississippi

ABSTRACT

Rice seed of the Bluebonnet 50 cultivar were stored under controlled environments of 20°C-75% relative humidity (RH), 30°C-52% RH, and 40°C-75% RH for 9 months. The progress of deterioration in the seed was monitored at monthly intervals in terms of standard germination percentage, germination percentage after accelerated aging (AA), and glutamic acid decarboxylase activity (GADA). GADA was the most sensitive measure of the progress of deterioration in rice seed but was closely followed by germination responses after AA. Deterioration was not reflected in a decrease in germination percentage—the traditional index of the physiological quality of seed—until it had substantially advanced.

Additional index words: germination, accelerated aging, glutamic acid decarboxylase activity, seed vigor, seed storage, relative humidity.
Rice seed deterioration is accelerated by increasing **time and temperature** in storage.

Concentration of **fatty acids** which are indicative of deterioration increased dramatically with increasing time and temperature.

Changes in fat acidity of rice during storage at different temperatures (●, 4 °C; ○, 20 °C; ▼, 30 °C; and ▽, 40 °C). Changes in physicochemical characteristics of rice during storage at different temperatures, Chan-Eun Park, Yun-Sook Kim, Kee-Jai Park, Bum-Keun Kim: Korea Food Research Institute, Republic of Korea
Effect of moisture content (MC) and temperature on respiration rate in rice:

Heat-damaged or “stack burned” rice occurring at 15%, but much worse at 25% MC.

Dry rice, below 12% MC.
Rice Seed Storage:

From small and simple

To large and complex...
Cool Grain to Prevent Storage Problems

*PREVENT CRUSING DUE TO MOISTURE MIGRATION BY COOLING GRAIN TO WITHIN 15° F OF AVERAGE OUTDOOR TEMPERATURES
*Cooling grain by 10° F doubles its allowable storage time

Dr. Kenneth Hellevang, PE
NDSU Extension Service
Fundamental Principle of Seed Storage:

Temperature (F) + Relative Humidity (%) = Less Than 100

Examples: 50°F + 40% RH = 90  This is OK
            35°F + 40% RH = 75  This is excellent

            80°F + 50% RH = 130  This is not OK
            95°F + 70% RH = 165  This is horrible and will lead to rapid deterioration of seed.

OK?
Storage conditions

Seed longevity is improved by storing seeds at low temperature and low moisture content.

Rule of thumb for seed storage
Seeds lose half their storage life:

1. For each 1% increase in seed moisture between 5 and 14%.

2. For each 5 degree C increase in storage temperature between 0 and 50 degree C.
Moisture Migration In Storage Bins:

Fall and Winter

Spring and Summer
Properties of air:

The best online psychometric calculator I have found is this one.
http://www.daytonashrae.org/psychrometrics_imp.html#start

The main item of information you can get from this is the dewpoint. If the grain is colder than the dewpoint you cannot run the fans because moisture will condense on the grain. You will have water running out of your bins after a few minutes, NOT GOOD!!!

You can also use a standard psychometric chart, but I suggest the online method.
Sling Psychrometer – used for determining wet bulb and dry bulb temperature, and relative humidity.
Situations To Avoid In Storage:

- Peaked rice in bins
- Fine material in core
- Only store DRY rice
- Scalp rice to speed drying and improve airflow in the bin.
## Table D. Rice Long Grain Equilibrium Moisture Content

<table>
<thead>
<tr>
<th>Temperature (°F)</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
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<th>65</th>
<th>70</th>
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<th>80</th>
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</thead>
<tbody>
<tr>
<td>35</td>
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<tr>
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<td>14.2</td>
<td>15.1</td>
<td>16.1</td>
<td>17.4</td>
</tr>
</tbody>
</table>

Try to stay within this range of parameters.
Structure and embryology of a rice seed:

- **A**: lemma
- **B**: palea
- **C**: embryo
- **endosperm** (beneath pericarp)
- **glume pedicel**

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X–Ray of checked rice grain.

Figure 5. Cultivar IRGA 420. X-ray of seed with severe damage (A), dead seed (B).
Mechanical damage and storability:

Damaged by heat, rapid drying and differential shrinkage – commonly termed as “checked”.

Some grains may be shelled and broken by abrasion and impact during harvesting and handling. Although many of these would produce seedlings their value as seed is lost.
Mechanical damage and storability of seed:

Rice seed of low moisture develop fissures (cracks or checking) when exposed to high relative humidity as occurs in the field (Kunze and Prasad, 1978).

Fissuring may also occur during drying (Kunze, 1979).

Dorfman and Rosa (1980) considered 40 degrees Centigrade (108 degrees Farenheit) as the optimum temperature for drying rice seed. Temperatures no higher than this were less likely to produce checking in rice grains.

Shelling of rice, or removal of the hulls, during handling can also reduce longevity of rice seed. Rice so affected is commonly referred to as hulled or brown rice. It is capable of germination for some undetermined period of time.
Embryology of a rice seed:
Supporting Issues:

• Insects
• Mites
• Diseases
• Rodents
• Birds
• Flooding (Elevation of storage facilities)
Storage Insects:
Pest of stored grains

• Insects
• Pathogens (fungi)
• Rodents
• Birds
Treat infested grain

Grain treatment
• Insecticides - several
• Fumigation
  • phosphine,
  • carbon dioxide

Physical
• Heat < 15, >55 (15mins)
• Impact
  • pneumatic conveyers
• Diatomaceous earth
  • dehydration
Fungi

Most common:
• Aspergillus and Penicillium
• Grain spoilage and mycotoxins (poisonous)

Influenced by:
• Moisture content of the stored grain
• Temperature
• Condition of the grain going into storage
• Length of time the is grain stored and
• Amount of insect and mite activity in the grain.
Common-sense principles for storing rice:

- Store only dry rice (below 12%)
- Monitor both moisture and temperature at least weekly.
- Only aerate when ambient relative humidity is below the dewpoint.
- Core your bins and re-level rice that will be stored long term.
- Don’t allow your confidence to cause you to let your guard down.
- Smell the first air that comes out of the door when fans are turned on. Should have clean nutty aroma. If not, move to another bin.
- Rice should not hold you up when you walk on it.
- Never enter a bin without someone watching you, and carry a safety line.
Precautions:

• Monitor moisture and temperature in storage at least weekly after dry rice is placed into the storage bin.

• Run fans on good days when temperature is low but not freezing and when relative humidity is below 50 percent.

• Never aerate when grain is colder than the ambient dewpoint to avoid condensation within the bin. This is one of the most serious mistakes you can make. Learn to use a psychometric chart and how to determine actual relative humidity. Do not use the local weather station for this.
Vigor:

A lot of very technical and academic statements can be made about seed, but the bottom line is whether they can produce a stand of healthy plants in the field.
The goals of preserving quality rice seed in storage:

This?

Or This?
This is the ultimate goal, to feed our families and reduce hunger around the world.
Thanks for participating in the 2015 Seedman’s Shortcourse and Mississippi State University.

A little bit of history can’t hurt. This is where many of us started.