Seed Conditioning Technology
(Part 1 of 2)

Agronomy / Horticulture 338
Seed Science and Technology
Fall 2017

Alan Gaul
Seed Conditioning Specialist
515-294-4011
agaul@iastate.edu

Review Topics
- Conditioning Applications
- Harvest & Storage Issues
- Material Handling Basics
- Separation Methods
  - Pre-cleaning / Preparation
  - Cleaning & Sizing
  - Upgrading Equipment*
- Treating & Packaging*
- Definitions & Quality Tests
- Pending Lab Discussions
  * more detail in 2nd presentation

Why Condition Seed?

- Soybeans
- Adzuki Beans
  - Threshing & Moisture Removal
  - Weed Seed & Foreign Material
  - Diseased & Immature Seed
  - Improve Appearance, Uniformity
  - Add Protective Coatings

Additional Conditioning Issues

- Harvest
- Seed Extraction
- Threshing
- Drying
- Specialized Treatments

General Conditioning Flow Diagram

Harvest
接收
前程
清洗
分离 & 升级

- 中西部的种子工厂正在逐渐变得更大、更复杂

Objectives:
- Remove All Contamination
- Minimize Seed Loss
- Remove Low Quality Seed
- Maximize Capacity
- Minimize Labor Required

Images Courtesy of Prairie Habitat and Seed Processing Holland
Basic Soybean Flow Diagram

Harvest → Pre-Cleaner → Bulk Storage → Air Screen Cleaner → Gravity Separator → Spiral/Belt Separator → Color Sorter → Seed Treater → Bagging Line → Finished Seed

Typical Flow for Seed Corn

Harvest → Ear Corn Plant → Pre-Cleaner → Color Sorter → Seed Treater → Bulk Storage → Bagging Line → Finished Seed

Harvest & Storage Concerns

Limit Mechanical Damage
- Reduce cylinder or rotor speed
- Avoid running at partial capacity

Maintain Quality in Storage
- Limit incoming moisture
- Pre-clean seed if possible
- Level bin and aerate properly
- Careful drying may be needed to reach safe moisture levels

Avoid Vareital Contamination
- Extensive cleaning is required

Ear Corn Harvest & Receiving

Picking → Husking → Receiving → Sorting → Drying → Shelling

Ear Corn Harvest Issues

ADVANTAGES
- Early Harvest of High Moisture Corn
- Field Loss Reduction (Fungi, Insects, Weather)
- Potential for Double Crop in Warm Climates
- Additional Time for Post Season Operations
- Visual Inspection for Quality Control

DISADVANTAGES
- High Initial Investment for Ear Corn Facilities
- High Labor Costs for Sorting & Handling
- High Fuel Cost for Drying

Husk & Sort Facilities

Truck Unloading → Distribution Conveyor → Feeder → Feeder → Feeder → Husker → Husker → Husker → Sorting Belt(s) → Sorting Belt(s) → Sorting Belt(s) → Discard → Husk & Discard → Ear Corn Dryer
**Ear Corn Dryer Type Diagrams**

- **Single Pass**
- **Double Pass**
- **Single Pass Reversing**

**Based on Airflow Pattern**
- Bin Qty for Series Airflow
- Airflow Direction Changes

**Key Differences:**
- Management Complexity
- Airflow Volume Required
- Energy Efficiency

**Ear Corn Dryer Types**

- **Single Pass**
  - Lowest cost per bushel
  - Small lots – shallow depth limits
- **Double Pass**
  - Modular independent bins
  - Relatively simple management

**Production Ear Corn Shellers**

- Axial Flow Configurations
- Round Bar or Perforated Cage
- Rotor Speed affects Seed Damage
- MUST maintain Product in Hopper

**Automated Shelling Lines**

- Typically Found at Larger Seed Research Operations
  - Sorting
  - Sheller
  - Cleaner
  - Color Sorter
  - Treater
  - Packeting

**Material Handling Systems**

- Elevator Legs
- Belt Conveyors
- Drag Flight Conveyors
- Vibratory Conveyors
- Pneumatic Conveyors
- Gravity Spouts and Letdowns

**Mechanical Damage during Conditioning**

Germination vs Sequence for 2 Moisture Levels
### Mobile Conveying Equipment
- **Portable Belt Conveyor**
- **Screw Conveyor**
- **Pneumatic Conveyor**

### Conventional & Continuous Cup Legs
- High Capacity
- Compact
- Easily Enclosed
- Lower Cost
- Vertical Lift Only
- Some Damage
- Boot Cleanout
- Limited Capacity
- Maintenance
- Higher Cost

- Typically for stationary vertical lift applications
- Trend for continuous cup leg designs for high value or fragile seeds

### Vibratory Feeders & Conveyors
- **Variable Feeder**
- **Receiving Conveyor**
- **Transfer Conveyor**

- Self Cleaning
- Multiple Outlets
- Limited Distance
- Moderate Cost
- Horizontal Only
- Vibration Issues

### Letdown Devices
- **Letdown Ladder**
- **Spiral Letdown**

- Commonly Used
- Easily Fabricated
- Modular Design
- Relatively Compact
- Can be Rubber Lined
- Multiple Small Impacts

- Less Common
- Eliminates Impacts
- More Difficult to Build
- Harder to Rubber Line
- Need to Match Spiral Slope to Seed Type

### Mechanical Damage Detection
- **Screen Shaker**

- **Percent Broken Seed**
  - Soybean - % Splits (10/64” Slot)
  - Corn - % BCFM (12/64” Round)

- **Seed Coat Damage**
  - Soybean - Soak Test
  - Corn - Fast Green Dye

### Minimizing Mechanical Seed Damage
- **Unloading**
- **Receiving Leg**
- **Belt Conveyor**
- **Air Screen Cleaner**
- **Cleaner Leg**
- **Inclined Spout**

- **Leg 1**
  - Screen Shaker

- **Belt 1**
  - Cleaner

- **Leg 2**
  - Cleaner Leg

- **Spout 1**

- Reduce seed velocity
  - Minimize drop height in spouts or transfer points
  - Use lowest RPM needed to provide required capacity
  - Use a larger conveyor running at lower speed
  - Use the lowest possible incline angle

- Reduce impact, abrasion, crushing or shearing actions
  - Eliminate pinch points and sharp edges
  - “Run in” conveyor to polish rough surfaces prior to use
  - Run most conveyors at (or near) Full Capacity
  - Consider rubber or plastic product contact surfaces
  - Modify conveyors if needed to avoid crushing seed

- Take extra precautions at cold operating temperatures
Dry Granular Separation Principles

- Separation based on Differences in various Physical Properties
- Common principles used:
  - Aerodynamics/Terminal Velocity
  - Approximate Seed Size
  - Seed Dimensions (L-W-T)
  - Seed Shape (Rolling Resistance)
  - Product Density
  - Color Differential
- Most “real world” applications require multiple techniques

Seed Cleaning - Physical Properties

- Aerodynamic Properties (terminal velocity): Aspirator
- Seed Size & Shape: Air Screen Cleaner
- Dimensional Separation: Length, Width, & Thickness Sizers
- Rolling Resistance: Spiral and Belt Separators
- Specific Gravity (Density): Gravity Separator & Destoner
- Color (UV, visible spectrum, NIR): Color Separator
- Surface Texture: Velvet Roll, Vibratory, Magnetic Separator
- Affinity for Liquids: Buckhorn Separator
- Electrical Characteristics: Electrostatic Separator

Types of Contamination

- **Foreign Material** - Plant parts, stones, dirt, bugs, etc.
- **Other Crop Seed** - “Alternative” crops
- **Weed Seed** - Other undesirable non-crop seeds
- **Mechanical Damage** - Chipped or broken seed
- **Varietal** - Other varieties of the intended crop
- **Physiological** - Physical or biochemical issues
- **Pathological** - Seed diseases and/or insect damage

Tools of the Trade (1/4)

- **Aspirator**
  - Vertical or inclined air column
  - Usage: Pre-cleaning or removal of light contaminants

- **Air-Screen Cleaner**
  - One or two aspiration columns
  - Multiple perforated screens
  - Usage: Removal of light contaminants, undersized, and oversized material
Screen Example

Air Screen Cleaner

- Air and Sieve Operations
- Removes FM, Light, Broken, Undersize, & Oversize Seed

Example - Air Screen Cleaner Results

Upper Air | Oversize | Undersize | Lower Air | Clean Seed

Flax | Soybeans

Screen Input

Oversize Material ("overs")
Undersize Material ("thrus")

Scalping Efficiency (oversize removal):
- Percent of Total Oversize Material passing "over" the screen
- Screen Capacity is limited by desired scalping efficiency

Sifting Efficiency (undersize removal):
- Percent of Total Undersize Material passing "thru" the screen
- Screen Capacity is limited by desired sifting efficiency

Screen Choice

- Achieves maximum removal of foreign material and minimum removal of good product
- Mechanical screen shaking equipment can be used to provide more consistent results and permit shaking tall screen stacks

Hole geometry & size determined by application
- Round
- Parallel Slot
- Triangular
- Cross Slot
- Wire Mesh

Layout affects capacity and screen efficiency
Size specified in English or Metric
Multiple screen sizes are typically used for most seed applications

Screening Terminology:
- "Scalping" - Removal of Oversize Material from Product
- "Sifting" - Removal of Undersize Material from Product
- "Sizing" - Dividing the Product into two Size Ranges
- Efficiency" is based on the desired operation type
Tools of the Trade (2/4)

**Indent Cylinder or Disc Separator**
- Indented pockets sized for length separation
- Usage: Separation of long from short material (ex: wheat/oats)

**Precision Sizer**
- Rotary cylinders with Round or Slotted perforated holes
- Usage: Sizing or removal of contaminants based on Width or Thickness

---

Seed Size Definitions

- Same thickness, different width
- Same width, different thickness
- Same width & thickness but different length

---

Length Grading – Indent & Disc Separator

- Removes Short or Long Seed from Primary Fraction

---

Laboratory Indent Cylinders

- Traditionally operated in “batch” mode
- Newer machines capable of either batch or continuous flow
- Used for Cylinder Selection and Cleaning Small Lots
- Adjustments include Size, Speed, & Trough Position

---

Disc Separator

- “V” (“Vetch”), “V”+Width (mm), V2.5 thru V6.5 separation
- “R” (“Rice”), “R”+Width (mm), R 3.5 thru R6
- Square (desticking), Letter Designation

---

De-Sticking Sunflowers

- Stems and sticks are hard to remove using conventional perforated screens
- Lifting sunflowers from sticks can be accomplished using either a disk or indent cylinder separator
Width and Thickness Sizer

- Width: Round Hole
- Thickness: Slotted

Sizing Flow Diagram (4 Sizes + Discard)

- Typical sizing stack uses multiple machines to create desired sizes
- Cylinder quantity is based on flow rate at each machine location
- Cylinder capacity depends on % "thrus" and desired efficiency

Sizing Cylinder Selection

Cylinder Selection Factors:
- Fractional quality evaluation
- Percent breakout by fraction
- Size range limits (plantability)
- Marketing requirements

Sizing Cylinder Capacity

- Capacity is typically rated at 95% efficiency (or higher)
- Cylinder capacity is higher for round hole configurations
- Cylinder capacity increases with higher percentage of thurs

Flat Screen Sizing (modular cleaners)

- Alternate to cylinder sizers on seed corn applications
- Limited evidence of reduced mechanical damage, possibly greater for round seed (Popp, 2003)
- Sizing efficiency is typically lower than for cylinders
- Capacity is less than equivalent air screen cleaner

Tools of the Trade (3/4)

- Spiral Separator
  - Inclined helical flights sloped to match rolling speed
  - Usage: Separation of spherical from non-spherical products

- Belt (roll) Separator
  - Inclined moving belts
  - Usage: More precise separation based on differences in rolling speed of various products
Shriveled or Oblong Seed Causes

- Immature Seed
- Diseased Seed
- Frost Damage
- Field Conditions
- Drought
- Other Factors

Static Spiral Examples

- Images courtesy of Profile Industries

Rotary Spiral Examples

- Single Core
- Multiple (4) Cores
- Core Replacement

Belt Separator

- Original "Draper Belt" design – single slope
- Later modified to use dual belt slope
- Provides multiple fractions, fewer collisions
- Multiple belts stacked to provide more capacity

Belt Separator Samples

- Round
- Flat
- Shriveled
- Single Belt

Gravity Separator

- Reciprocating inclined fluidized bed to "float" light from heavy
- Usage: Density separation of light weight or heavy product

Color Sorter

- Optical separation based on differences in color or intensity
- Usage: Removal of dark and/or light discolored material

Tools of the Trade (4/4)
**Fluidized Bed Density Separation**

- Destoner
  - Two Density Fractions
  - Removes Heavy Material

**Gravity Separator**
- Continuous Density Range
- Multiple Fractions Possible
- Removes Low Density Seed

**Gravity Table**

**Optical Detection & Separation**

- Color Sorting Equipment
  - Provides Two Color Fractions
  - Removes Light or Dark Material

**Treating & Coating**

- Seed Coating
  - Provide Pathogen Protection
  - Improve Planter Performance
  - Better Product Appearance
  - Increase Seed Size (Pelleting)

- Seed Pelleting

**Seed Treating Equipment**

- Automatic Batch
  - Continuous Flow
  - Used to Apply Treatment or Coatings:
    - Correct Proportion of Seed & Chemical
    - Acceptable Appearance & Product Flow
    - Proper Application Rate
    - Uniform Seed Coverage

**Packaging**

- Package Type Factors:
  - Market Requirements
  - Volumetric Issues
  - Desired Automation
  - Downstream Handling Equipment Availability

- Bulk Bag Filling

**Storage and Shipment**

- Warehouse Considerations:
  - Space Requirements
  - Material Handling Facilities
  - Possible Climate Control
  - Traffic Control and Security
Common Quality Control Measurements
- Moisture Content (%)
- Test Weight (lb/bu or kg/hectoliter)
- Broken Seed (BCFM or Split %)
- Seed Coat Damage (%)
- Seed Count (seeds/lb, TKW)
- Visual Defects (%)
- Packaged Units (weight or count)
- Flow Rate (lb/hr, bph or tons/hour)
- Discard or Fraction Percentage (%)
- Separation Efficiency (%)
- Good Product Yield (%)
- Defect Concentration (%, G:B ratio)
- Measurement variability

Moisture Measurement Technology
- Air oven dryer is the measurement standard
- Other meters are calibrated against oven
- Electrical meters - resistance, capacitance, or near infrared (NIR)
- Brown-Duvel - high MC, frozen seed

Density Definitions

**Bulk Density**
- Typically called "Test Weight" for most seed applications
- Weight of a given volume of seed, INCLUDING void spaces
- Measured by weighing a container filled under controlled conditions
- Very commonly used for both seed and grain applications

**Particle Density**
- Sometimes also called "Kernel Density" or "Seed Density"
- Weight of a seed volume EXCLUDING void spaces
- Seed volume measured by liquid displacement or a gas pycnometer

**Specific Gravity**
- Ratio of particle density to water (specific gravity of water = 1.0)

Test Weight Devices
- Bulk density measurement
- Weight per unit volume
- English – lbs per bushel
- Metric – kg per hectoliter
- Tends to correlate well with seed quality parameters

Split and BCFM Percentages
- Splits – Based on 10/64 Slotted Screen (%)
- BCFM (Broken Corn & Foreign Material) – Based on 12/64” Round Screen
- Screen Shaker to Minimize Variability (30 strokes)
- Typically 500g or larger sample

Seed Coat Mechanical Damage Tests
- Sodium Hypochlorite Soak
- Dilute Bleach Solution (5:1)
- 5 Minute Soaking Interval
- Fast Green Dye Test
- Commercial Dye Solution
- Stains Exposed Starch
- Minimal Damage
- Limited Staining
- Good Quality
- Slight Damage
- Minor Staining
- Storage Concerns
- Severe Damage
- Embryonic Staining
- Poor Germination
- Minimal Damage
- Limited Staining
- Good Quality
- Slight Damage
- Minor Staining
- Storage Concerns
- Severe Damage
- Embryonic Staining
- Poor Germination
Visual Defect Percentages

- Visual Observation (light & dark %)
- Possible to partially automate using fast green dye, image processing, or other methods
- Tends to be very subjective - operator effects

\[ \text{BadGoodRatio} = \frac{\text{DefectQty}}{\text{GoodQty}} \]

\[ \text{SortEfficiency} = \frac{\text{Reject}_\text{Defect}_\text{Qtty}}{\text{Total}_\text{Defect}_\text{Qtty}} \cdot 100 \]

Typically tracked over time to monitor for possible process changes or optimize adjustments.

Seed Count / Size Relationships

- Seed is a biological product with variable size, shape, and density
- Seed Count provides an approximate way to quantify average seed size
- The result tends to vary based on seed dimensions, shape, and weight
- Units are typically expressed as either seed count (seeds/lb) or TGW (grams per 1000 seeds)

Conversion Equation:

\[ \text{Seeds/lb} = \frac{453.6 \times 1000}{1000 \times \text{Seed}_Wt} \]

- Sample size is application dependent

Typical Seed Counter Applications

- Rough estimate of seed size for a given variety or seed lot
- Quantify differences between seed sizes within the same lot
- Estimate seed size differences between multiple fractions from gravity tables or other separation processes
- Calibration of weight-based seed treaters for newer systemic products using “per seed” application rates
- Quantify blend proportions for integrated refuge products
- Calibration of weight-based bagging scales for high volume bagging operations and seed quantity based labeling
- Packet filling for research or high-value seed applications
- Newer devices may provide additional sample analysis tools

Mechanical Seed Counter Examples

- Multiple feeder designs
- Total vs Batch Operation

Counter Calibration

- Calibration sample - ten sets of 100 seeds each
- Combine the 10 sets and carefully pour 1,000 seed calibration samples into counter
- Start the counter and run until all seeds have been counted
- Final count should be within +/- 2 seeds
- Adjust counter and repeat test if required

Effect of Counting Speed on Seed Count

- Limit Speed for Accurate Counts
- Compensate for Seed Size
New Optical Imaging Counter

- Loaned by Process Vision (Richmond, VA)
- Rapid 2D counting and sample analysis
- Evolving to include additional capabilities
- Also using to analyze spiral testing results

Basic Separation Efficiency Concepts

- Defined by the intended process goals
  - Recovery (removal) of contaminants ("removal efficiency")
  - Recovery of good product ("good product yield")
  - Separation efficiency (seed recovery adjusted for discard levels)

- Complete contaminant removal will typically also remove a small amount of good product

Sample Flow Calculations (Defect Removal)

Given weights of timed samples from each fraction
- Can estimate flow rate and fraction percentages
Grade samples to determine defect concentration
- Can also estimate defect removal rate
- Similar calculations possible for most operations

Sample Flow Calculations (Yield)

Given weights of timed samples from each fraction
- Can estimate flow rate and fraction percentages
Grade samples to determine defect concentration
- Can also estimate defect removal rate
- Similar calculations possible for most operations

Statistical Process Monitoring (SPC/SPM)

"Process watching" for change detection

Examples:
- Xbar (average)
- Range (max-min)
- Standard Deviation (s)

Overall variation components:
- Random, Short Term Baseline
- Non-random, Long Term Variation (to be eliminated)
Review and Discussion

- Typical seed separation methods are based on physical differences
- Machine principles may involve size, shape, density, and/or color
- Multiple machines can improve results and minimize seed loss
- Process sequence can often be important for good results
- Understanding characteristics of various contaminants and related equipment capabilities can be useful for difficult separations

Seed Conditioning Lab Location

Pending Lab - Seed Corn Process

- Shelling & Aspiration
- Air-Screen Cleaner
- Color Sorter
- Sizing
- Gravity Table
- Seed Treater
- (Packaging)

Seed Conditioning Lab - Upper Level

1 - Sample Analysis & Cylinder Verification

- Clean seed prior to sizing
- Create 4 seed sizes
- Evaluate size %, seed count
Station 2: Satake Color Sorter

- Review Operation at four dark trip levels
- Each group runs one setting
- Collect timed sample weights
- Evaluate sample quality
- Calculate: % Discard by Fraction and Defect Removal Efficiency

Station 3: Sizing Stack

- Timed samples have been collected in advance to save time
- Evaluate each sample to verify sizing efficiency for each stage
- Estimate flow rate, sized fraction percentage, and efficiency

Station 4: Oliver Gravity Separator

- Review concepts and demonstrate operation
- Collect 3 timed sample weights - Light, Medium, and Heavy (1 per group)
- Record sample weight and related run time
- Lab sample analysis

Station 5: BMC Batch Seed Treater

- Review basic components, product flow, and operation
- Verify chemical and seed metering rates using closed circuit calibration tubes and timed sample weights
- Given: Initial batch weight, pump speed and cycle time
- Calculate: Estimated seed capacity, chemical application rate, and anticipated hourly chemical usage

References & Acknowledgements

- Seed Conditioning - Technology. Volume 2A-B. Gregg, B.R. 2010
- Seed Processing and Handling. Vaughn, Gregg & Delsouche. 1968
- Managing Grain After Harvest, Bern. 2005 (AE 469/569 textbook)
- Seed Science and Agronomy Department archives
- ISU Seed Science workshop presentations (2006-2013)
- Various websites, including www.gipsa.usda.gov (seed images)
- Various Industry Brochures, Operator’s Manuals, and Discussions:
  - Advanced Sort Industries - Seymour, IN
  - AEC Enterprises - St. Charles, Iowa
  - ArrowCorp, Inc. – Winnipeg, Manitoba
  - Ball-Coleman (ST5) - Chicago, IL
  - Buhler Sortex - Stockton, CA
  - Carter-Day Int'l - Minneapolis, MN
  - Cimbria Bretony Co. – Urbandale, IA
  - Crippen Manufacturing - St. Louis, MI
  - Forsberg's, Inc. - Thief River Falls, MN
  - Harada Sanyo - Ageo, Saitama, Japan
  - LMC Manufacturing – Donaldsonville, GA
  - Kice Manufacturing - Wichita, KS
  - Oliver Mfg. – Rocky Ford, CO
  - Profile Industries - Rogers, MN
  - Westrup USA - Dallas, TX
  - Satake USA - Stafford, TX
  - Seedburo – Chicago, IL
  - Universal Industries - Cedar Falls, IA

** Thanks for your continued support for the ISU Seed Conditioning Program **