Cornell University
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OGRIN

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NORTHEAST ORGANIC FARMING ASSOCIATION NEW JERSEY

Grain Cleaning, Drying, and Storage Systems

Sponsored by:

Organic Growers' Research Information Sharing Network &

Natural Organic Farming Association – New Jersey

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NORTHEAST SARE
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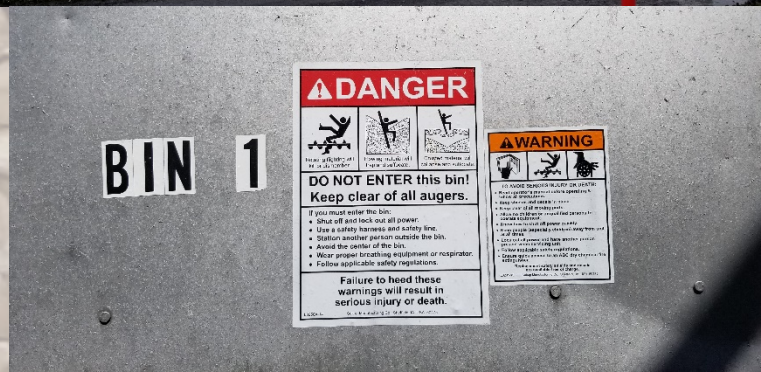
Agenda

- Grain System Considerations
- Comparison of Some Capital Costs
- Pictures & video tour of Langdonhurst Farm
  - Q & A with John Langdon
- Pictures & video of Hudson Valley Hops & Grains
  - Q & A with Stuart Farr
- Video discussing grain storage in sacks
- Pictures & video of other drying & cleaning machinery
- Discussion

Grain System Considerations

- Costs – capital and variable
- Efficiency *($25/hr labor minimum?)*
- Longevity
- Management – SLAM
  - Sanitation
  - Loading
  - Aeration
  - Monitoring
- Safety
- FSMA (Food Safety Modernization Act)





Recent Recalls Due to Pathogens in Flour

- Cold Stone Creamery – 2005 (Recall)
  Cake Batter Ice Cream - Salmonella
- Nestle – 2009 (Recall)
  Refrigerated cookie dough products
  E. coli 0157:H7
- Rich Products – Various – 2013 O121 (Recall)
- Pizza Ranch – March 2016
  13 illnesses – E Coli 0157
- Gold Medal Flour – 2016 (Recall – 3)
  63 illnesses – E. coli 0121/026
- Flour – Canada – Ardent March 2017 (Recall)
  Robin Hood & others
  30 Illnesses – E. coli O121
- Flour – Canada – Rogers Foods – May 2017 (Recall)
  6 illnesses – E. coli O121 (Costco)
- Flour – E Coli – Smuckers of Canada – Feb 2018
  No Illnesses
- Duncan Hines Cake Mix - October 2018 (Recall)
  5 illnesses – Salmonella
- Flour – January 2019 (Recall)
  No Illnesses – Salmonella
- Gold Medal Flour – January 2019 (Recall)
  No Illnesses Salmonella
- Pillsbury Flour – March 2019 (Recall)
  No Illnesses – Salmonella
- Aldi Flour (exp to King Arthur, Pillsbury, Brand Castle) May 2019 (Recall)
  21 Illnesses – E. coli O26
- Gold Medal Flour – September 2019 (Recall)
  No Illnesses – E. coli O26
- King Arthur Flour – October 2019 (Recall) [Expansion of May]
  No Illnesses – E. coli (Also Robin Hood in US)
- Wild Harvest Flour – November 2019 (Recall)
  No Illnesses – E. coli
- Hodgson Mill Flour – November 2019 (Recall)
  No Illnesses – E. coli

Notes

- No matter the size, all operations need to plan for efficiency. If you are running a small flour mill to sell fresh flour at a store front, how much labor expense is there if you mill 20 – 30 lbs/hour? For big operations, every time you move grain, it costs labor, machinery, and energy.
- The Food Safety Modernization Act applies to large food and feed grain processing facilities. However it affects all farms that are selling grains to regulated mills. Additionally, the protocols are useful guidelines for all farms and mills to follow to ensure a safe food and feed supply.
- There have been several safety recalls of grain products over the last few years.
- Safety is important for all farms and facilities. Have you every fallen because of loose grain on the floor (wheat & rye are like little ball bearings)? Trucks should never have to back up. Safety requires that facilities be well-planned.

	Grain Storage Systems Comparison		
Type of System	**Capacity**	**Dimensions**	**Capital Cost**
Flat Bottom Bin	14,112 bu	30ft dia X 22ft H	$39K, $2.76/bu
Flat Bottom Bin	5613 bu	21ft dia X 18ft H	$24K, $4.28/bu
Flat Bottom Bin	2785 bu	15ft dia X 18ft H	$17.5K, $6.28/bu
Hopper Bottom Bin	945 bu	9ft dia X 26ft H	$10K, $10.58/bu
Hopper Bottom Bin	1470 bu	12ft dia X 22 ft H	$12K, $9.52/bu
Hopper Bottom Bin	9373	24ft dia X 13 ft H	$40K, $4.27/bu
20ft Shipping Container	1044 bu	8ft W X 8 ½ ft H	$2900+, $2.77/bu
40ft Shipping Container	2116 bu	8ft W X 8 ½ ft H	$3900+, $1.83/bu
Kilbros Grain Box only	205 bu (72 bu/ft rise)	88 ½ “ X 12 ft	$3300, $16.10/bu $3400, $12.27/bu
Kilbros Grain Wagon	205 bu (72 bu/ft rise)	8 ton running gear	$6500, $31.70 $6600, $23.83
Pallet Bins, hopper bottom	16 bu	57”X45”X32”H	$381, $23.81/bu
Pallet Bins, hopper bottom	47 bu	57”X45”X65”H	$529, $11.25/bu
Home-made wood bin			????
50# Nylon Bags	50 lbs?	24” X 40”	$0.80 ea
50# Burlap Bags	50 lbs?	24” X 40”	$2.00 ea
1 ton Totes	45 bu	42”X42”X55” spout	$47, $1.05/bu
LABOR $25/hr			

Notes

- The prices in the Comparison Table are ballpark new prices from single sources. I did not shop around.
- Metal bin prices are include the cement base, aeration floor, unloader auger, ladders, fan, etc for a complete bin.
- Shipping container prices are for USED. Prices for shipping containers fluctuate widely and often.
- When you select a grain system, consider the capital cost per bushel, longevity (bags may only last a couple of uses, and the efficiency of handling grain. Labor can make inefficient small-scale systems very costly.
- Large hopper bottom bins capital costs can similar to flat bottom bins.
- In flat bottom bins, last grain in is the first grain out (it flows down into a central cone). In hopper bottom bins, the first grain in is the first grain out (the grain mass slides down as one mass).
- You can probably make your own wooden pallet bin. Currently lumber prices are very high ($52/sheet of plywood). If you have your own lumber, that may be an advantage.
- For small-scale systems especially, the key is to find a good deal. New gravity wagons and pallet bins are expensive. Being able to shop for equipment, repair, and fabricate is needed to keep capital costs low.

Component	Capacity	Price
screw in aerator fan tube	???	$98 - $270 $124+
GTE 245 Batch Dryer	140 bu/hr 2.2 mil BTU/hr 10,800 CFM	$29,000 (290K bu @$0.10; ~5800 acres to cover capital cost
4” corrugated drainage pipe	100 ft	$66
Rocket Bin Dryer for hopper bottom bins		??
4” X 10ft auger, motor, boot		$800
4” X 20ft auger, motor, boot		$950
6” X 10ft auger, motor, boot		$1,100
6” X 20ft auger, motor, boot		$1,400

Notes

- When you design a grain storage system, learn and understand the principles of grain storage, aeration, pest management, etc. A poorly designed system will cost you lots of money.
- Some manufacturer websites (like corrugate aeration pipe) for have design information.
- Companies that sell grain systems should be able to design a system to your needs.

Tour of Langdonhurst Farm & Discussion

https://youtu.be/Qm3MHxewFZ0

Notes

- The grain storage principles for a large operation like Langdonhurst Farms, apply to all size operations, from bags to bins.
  - What is the moisture content and temperature of the grain at harvest?
  - How long can it be stored at the moisture and temperature?
  - How will the grain initially be held (in what structure/bag) and what is the capacity of the system to deliver heat and air to dry it.
  - Storage structure volume and fan capacity must be matched properly to deliver the need cubic feet per minute (CFM) of air.
  - If the grain is heated to dry it out
  - For long-term storage, how will grain temperature be cooled as winter progress to keep it within 15^{O} F of the average monthly temperature. The grain must be cooled down in steps as winter temperatures drop.
  - There are references to grain storage manuals at the end of this presentation that you need to design storage, aeration, and drying systems.
  - A continuous grain dryer is shown in the video There are many types of these dryers.

Tour of Hudson Valley Hops and Grains & Discussion

https://youtu.be/93cOiclKuBM

Notes

- Efficiency is the key point of Hudson Valley Hops and Grains since Stuart is mostly a one man operation. Labor quickly adds cost when operating a small operation. If labor costs are $25/hr at a minimum (really $30 - $40 with taxes & insurance), you have to process a lot of grain to cover out that expense. Also consider the fixed expenses of buildings and machinery ownership. Yes, some people will pay $5 to $7/lb for a specialty grain, but that is a special market. Along with the need to be profitable, I feel that we have the responsibility to provide nutritious food at a reasonable price.
- To manage pests and rodent, whole grains are stored in bins using good management practices to prevent pests. Then when grains are processed (de-hulled, crimped, squeezed for oil) and bagged, the product is sold immediately and not stored. Bags of product sitting around is how rodents and pests build up.
- When buying in grains, test for moisture, bugs, and dangerous materials (rodent excrement) BEFORE you unload. Think FSMA!! Once you reject a load (and show the reasons why), the lesson is learned.

Video of Clipper Grain Cleaner & Discussion

https://youtu.be/hIUIHAwUo08

Notes

- The clipper and other cleaning machines need to be adjusted for the lot of grain being processed. Grain characteristics and cleaning performance change with the year, variety, field, humidity of the day, etc.
- When selling to large mills, grain price will be discounted if it does not meet the required specifications of moisture, level of foreign material, broken kernels, etc. From what I see, those discounts are actually small, so that it may not pay to spend a lot of money cleaning grain. HOWEVER, to develop a trusted relationship with your buyer, only deliver a good quality product. Otherwise, when a buyer needs grain, you will be the last on the list of suppliers.

Tour of Storing Grain Bags in Insulated Trailers & Discussion

https://youtu.be/rXsHGt9p_VI

Notes

Comments from Joel Steigman and Henry Beiler

- **Refrigerated trailers are insulated which improves storage conditions. Rapid and large changes in temperature cause storage problems; sometimes even when grain is dry.**
- **Trailer floors need to be smooth to easily manage a pallet jack.**
- **Use four-way pallets**
- **Do not let bags hang over the sides of the pallet**
- **Use solid surface pallets or place a cardboard sheet on top of the pallet so that bags do not sag between the boards and get poked by pallet forks.**
- **Do not store bags in a barn otherwise they will absorb humidity. Rodents will also be a problem.**
- **Insects have not been a problem in bags stored in insulate trailers. The grain must be dry and not be infested in the first place. Broken kernels provide food for secondary insect pests like the Indian meal moth, grain beetles, booklice (psocids).**
- **Joel Steigman uses a CV Tech Bagger (Middleby Food Processing, $30K) to vacuum pack 50 lb bags. A CO_2 generator is used to flush out oxygen with carbon dioxide, then a vacuum applied before sealing the bag. Pests can live in side. An adjustable table and conveyors are part of the system.**

I have seen totes of dry rye stored in an nice barn, but all fall there was rainy humid weather. The grain on top absorbed moisture and began to sprout. Plan for difficult conditions.

Refrigerated seed storage unit, Lamar Stauffer, New Holland, PA



Used 9 ft X 21 ft refrigerated trailer

Lamar grows wheat, spelt, hulless oats, barley, and einkorn



Can also use an air-conditioner converted to a “Cool-Bot”



Totes & bags stored,
Space for eighty 50-lb bags



Keep temperature <55^{O} and
< 50% humidity, no bugs

High Meadows Farm

- 20 ft shipping container (13 tons feed); 40 ft (24 ton)
- Space inlet based on natural slope of piled grain
- Gets very hot in the summer
- No moisture migration or spoilage (feed out grain continually)
- Exhaust vent for drying







A bulk head is needed to open doors and hold the grain.
This slot can be used to construct a bulk head.



With innovation you can layout drainage pipe or build/install an aeration floor, fit a fan, and auger out most of the grain.

- ***The area of slots in 100ft of 4" drainage pipe = to the area of the pipe cross-section area (12.56 in^2), but labor efficiency??***



Notes

- High Meadows Farm uses these used storage containers for feed. They are filled periodically and each day feed is taken out for the organic dairy herd. So material is always moving. Storing grain is a different process and creates different conditions.
- A 20 ft container needs two inlet holes and four are needed in a 40 ft container to completely fill it. Each grain has a different angle/cone at the top of the pile when it falls freely. It spreads out only so far.
- Consider the un-insulated metal walls, which will get very cold in the winter. This will facilitate "moisture migration" (condensation) if grain is not properly dried and the aerated to manage its temperature. I do not think that you can just put dry grain in a container and leave it for months without aeration to keep its temperature within 15^{O} F of the monthly average temperature.
- The container gets very hot inside during the summer. This may reduce seed viability and accelerate pest development. Temperature swings will be great and create moisture migration/condensation. Adequate aeration is needed. If you put 18% moisture grain inside at harvest, it will only last about 3 days before being spoiled.
- Perforated irrigation pipe or an aeration floor can be installed. A bulk head needs to be built in front of the doors to open them without spilling grain. A short access pipe can be installed to insert a auger to remove grain. The question efficient will it be to remove the last bit of grain. Some hand shoveling will be required. This can be minimized with a creative floor design.
- Exhaust vents would need to be installed, sized to you aeration capacity.





Hudson Valley Farm Hub

- Storing grain in a building Minimizes temperature change & will reduce moisture migration
- Locating storage in a building or at least minimizing direct sun can be beneficial
- Grain in sacks will take on moisture from humid air

B & W portable aerator

- Not rated for air flow (CFM), so experience is needed to understand it capacity
- For drying grain ***only*** a couple points of moisture.
- Depends on which grain, initial grain temperature, initial grain moisture, amount of chaff, humidity, etc





Hickory Hill Farm

- The pipe is a loop, not dead ended, to equalize pressure better
- Attaching pipe to a plenum (box chamber in front of the fan) might increase the air flow









Renauld Farm

- 4 - 5 tons rye in a grain cart
- Auger or gravity flow into a loader bucket, then dump into the customers truck
- Some rodents and squirrels (think FSMA)
- No storage mold (moisture test at harvest and mix field edges with dry areas)

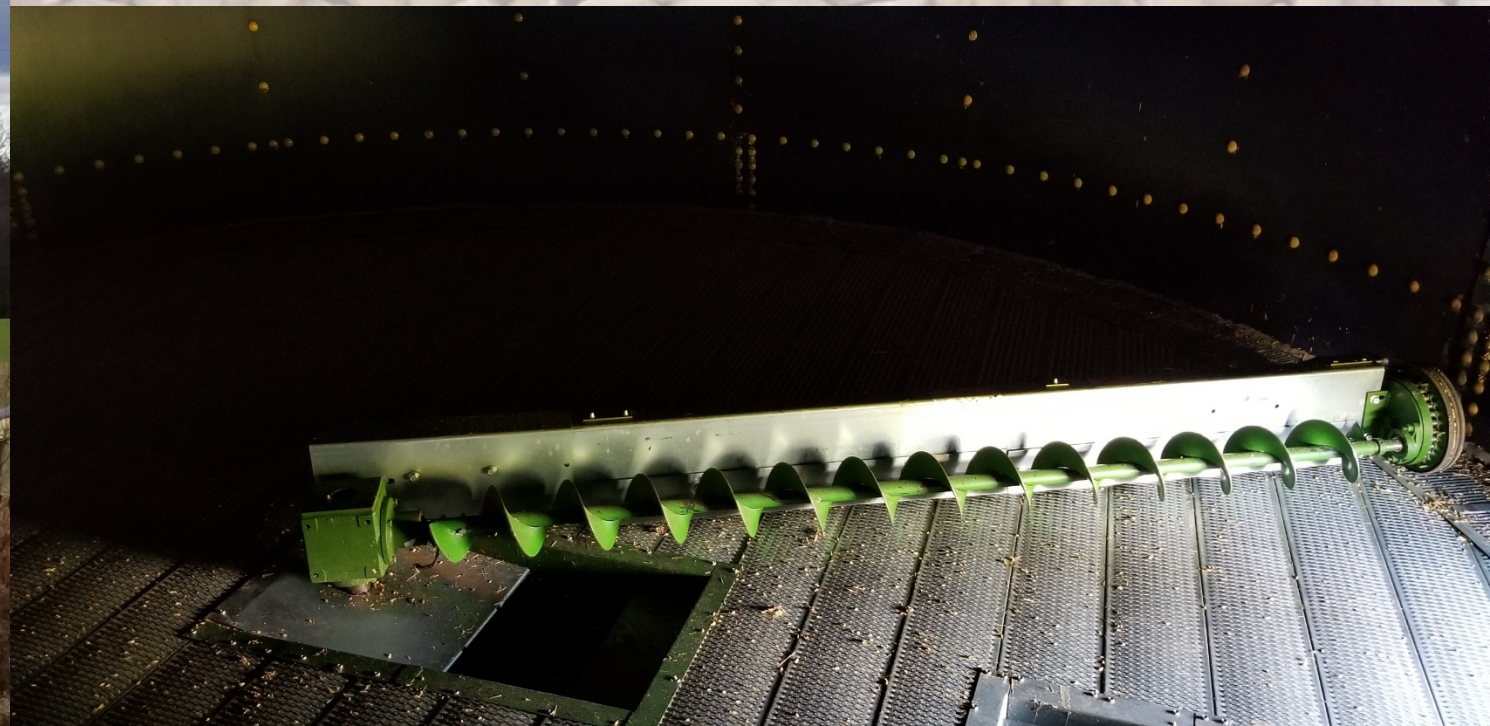
Notes

- Mark Renauld grows rye and sells it for cover crop seed. Squirrels eating at the top of the bin is not a big issue. It would be if the grain was used for feed for food.
- Tight fitting covers are available to keep out dirt and pests.
- Mark has no drying system. He waits for grain to dry in the field. Often there are green spots along field edges. So those spots are harvested and mixed with dry parts of the field to even out moisture content in the grain.
- Buying new a gravity wagon to store grain is too high a capital cost. If you say $1/bu for storage (double the normal custom contracted storage cost), then it would take 23 years to payback a new gravity wagon. Find a good deal on used carts fi that is the system you choose.
- As you saw in the video of Hudson Valley Hops and Grains, gravity wagons can be modified to dry grain as well.



Migliorelli Farm

- 16 ft X 48 ft, 148 tons barley, 7716 bu
- Flex sealed all seams & bolts
- Roof needed work. Blue roof is better
- About $2.50/bu to convert the silo
- Grain sweep needs to be lifted up before filling bin. It runs over the top of the pile remaining on the floor.



Migliorelli Farm

- Grain Vac does a great job of filling the bin
- Concrete silos can also be converted to store grain if they are in excellent condition
- An engineer is needed to evaluate and design the conversion





Corn Cribs

- Corn needs to get air to dry out, so crib dimension are important
- The older publication, “Storing Corn” is available with other resources for this meeting, and has information about constructing corn cribs
- Little information on pest management in corn cribs: keep rodents out; no broken kernels; get corn dry (apply air if necessary). Dry whole kernels are resistant to insects and molds.



Principles – Grain Drying
Moisture Front

- **In a bin or bag, air moving in one direction carries and concentrates moisture in that direction.**

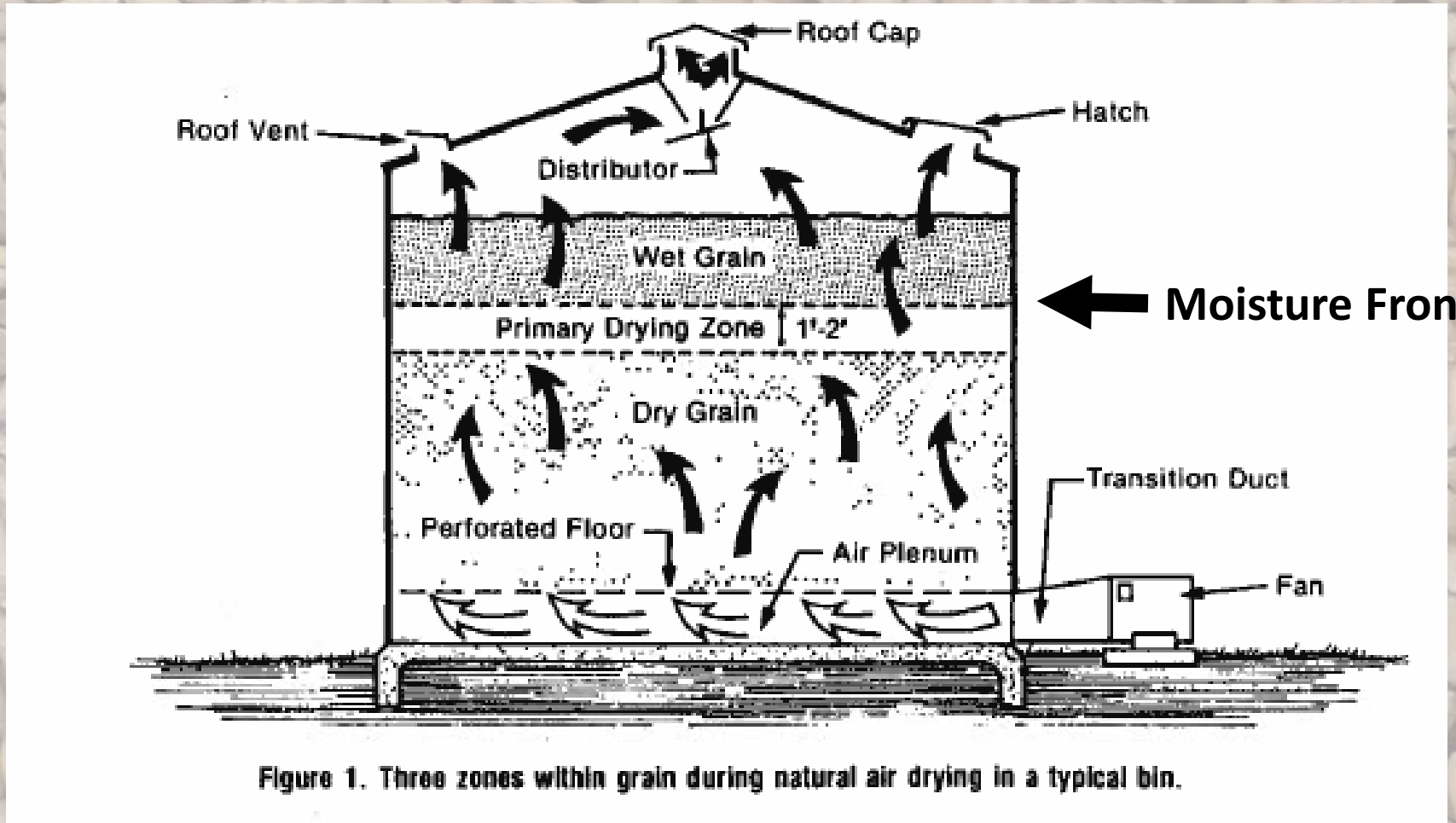


Figure 1. Three zones within grain during natural air drying in a typical bin.

Principles – Grain Drying
Moisture Migration

- Condensation occurs when there is >15^{O} difference in temperature between grain and air.
- As air temperature decreases into the winter, grain is cooled step wise using aeration to cool it down and keep it within 15^{O} of the monthly average temperature.
- Grain should be monitored every two weeks for moisture, temperature, and pests: use a thermometer & moisture meter; smell the grain as soon as a fan is turned on; look for condensation; use traps to monitor pests.

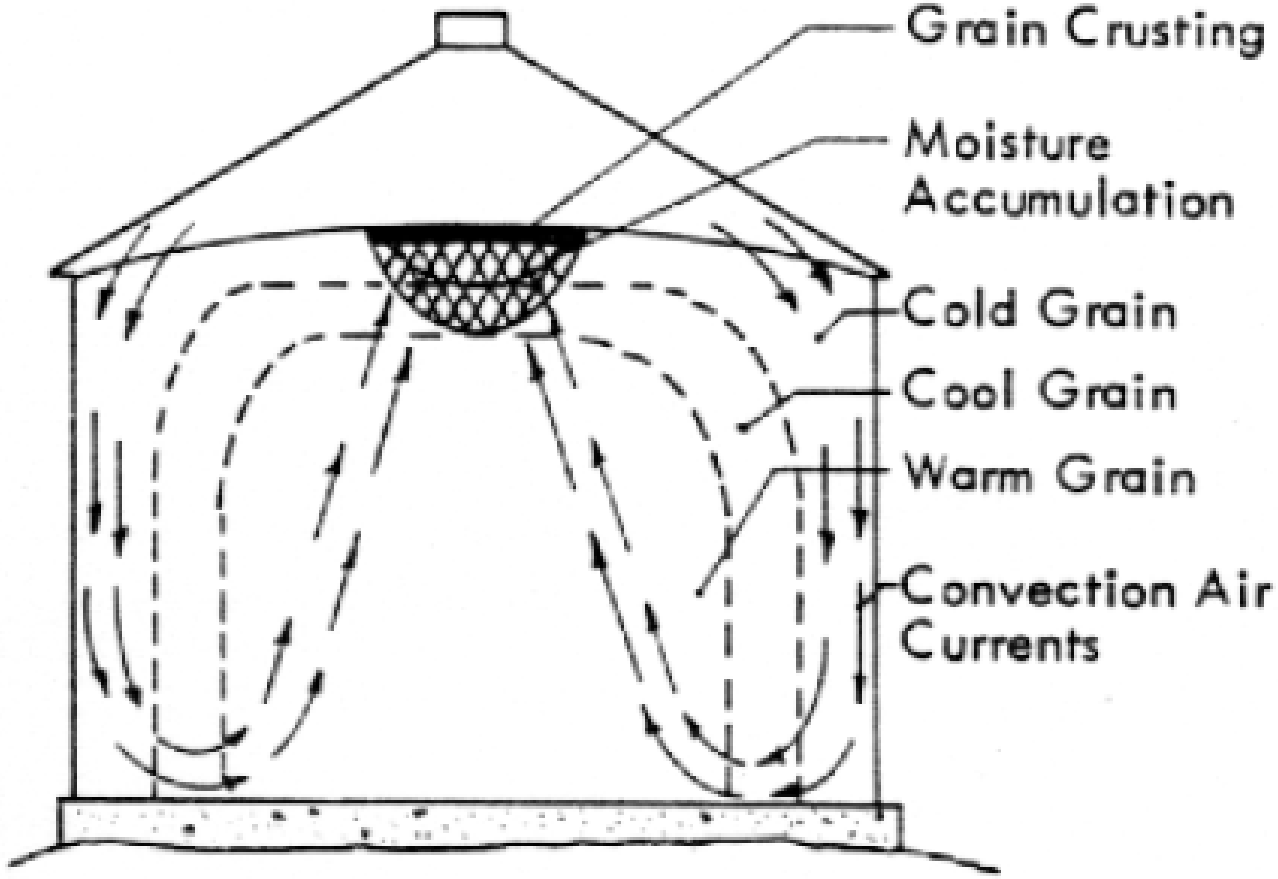


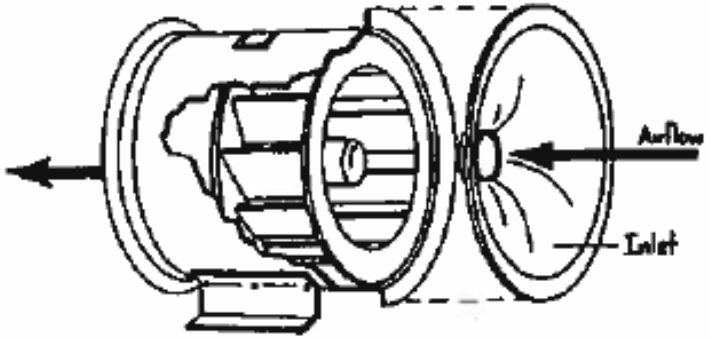
Fig 1. Winter grain temperatures and moisture migration

Principles – Grain Drying

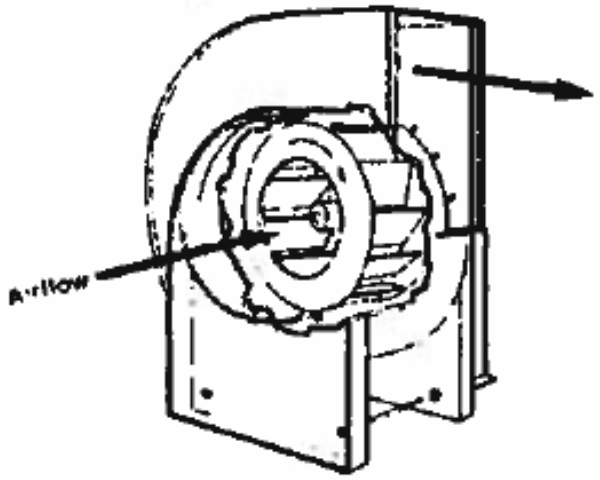
Fans perform differently

- All fans should have manufacturer's performance data: CFM @ different static air pressures
- Grain storage manuals have charts to provide ballpark data to design systems.

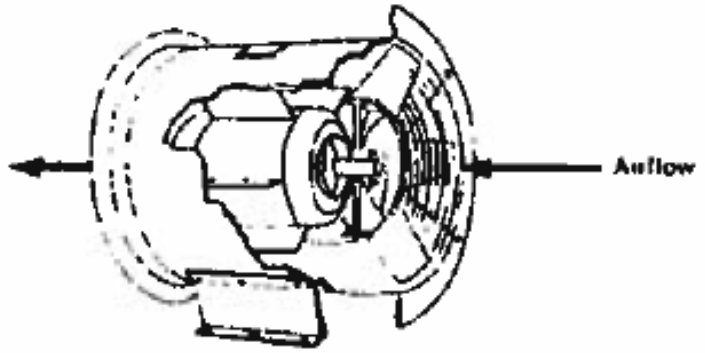
COMMON FANS USED ON GRAIN SYSTEMS



In-line centrifugal fans develop higher pressures than an axial-fan at a lower cost than a normal centrifugal fan.



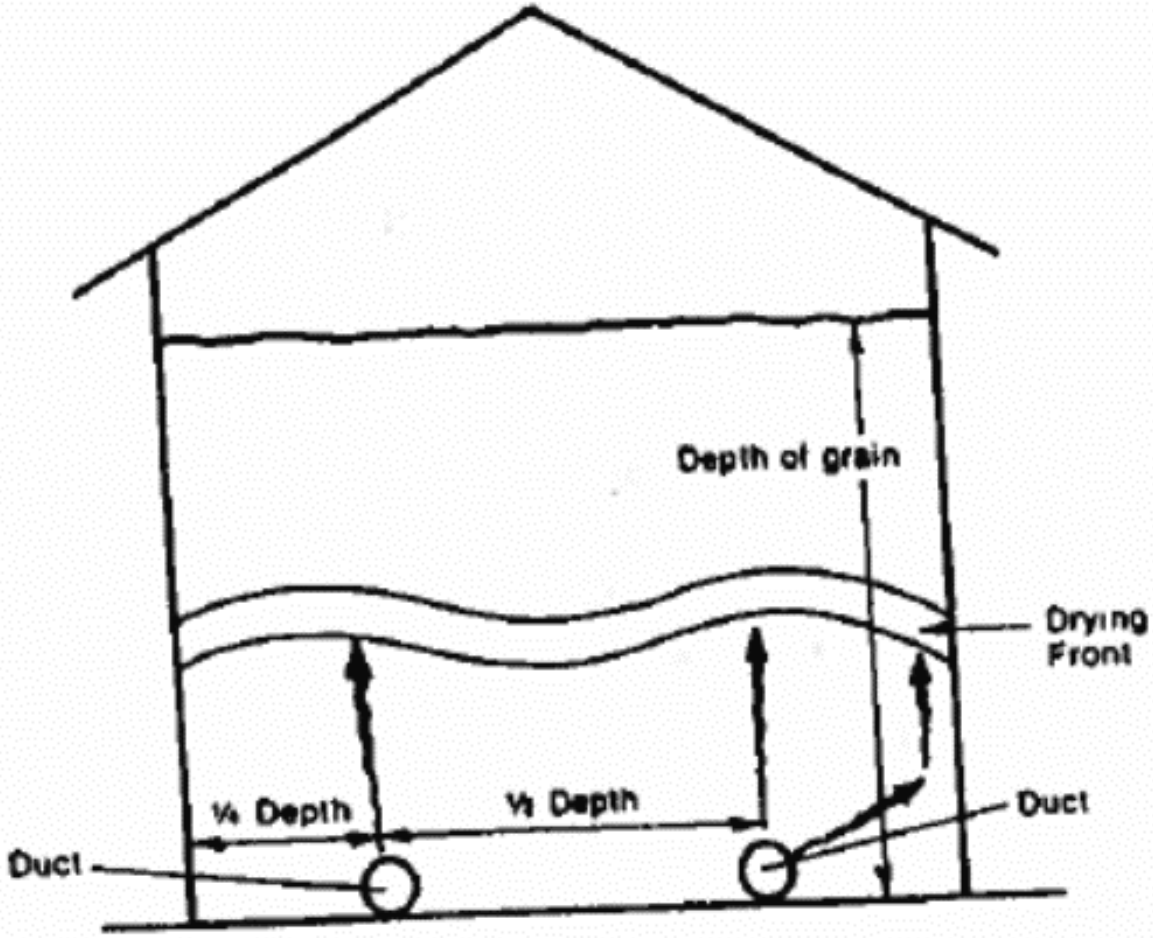
Centrifugal fans require higher investment than axial-flow fans, but are more efficient at higher static pressures and are quieter. They normally operate at 1,750 or 3,500 rpm.

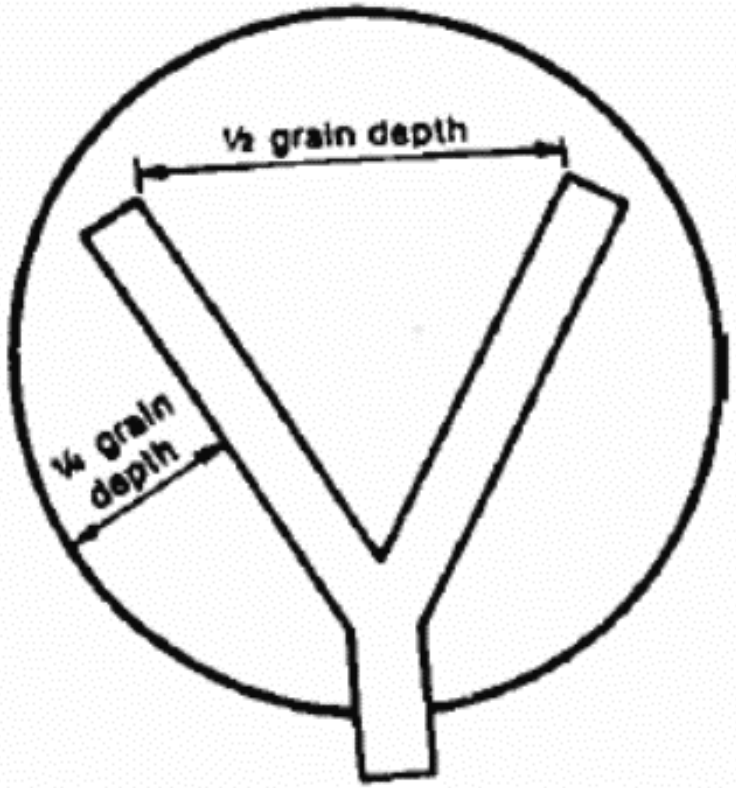


Axial-flow fans operate most efficiently at static pressures below 3 to 4 inches of water. Noise can be a problem.

Principles – Grain Drying

- If you use a bin, bag, pile, or whatever, consult established engineering data to properly design you system (in the manuals at the end of this presentation).





Tools for monitoring moisture and temperature





Notes

- Never trust the accuracy of any thermometer until you check it against a know temperature (calibrate it). Most thermometers are not calibrated when they arrive to you.
- I purchased the 15-foot temperature cable for my Craftsman Multimeter (it has a temperature function). The cable is off by 15^{O} . I can still use, but must adjust it by 15^{O} . Most thermometers will be off by a couple of degrees.
- It is important to check the temperature in different parts of the grain mass to be sure it is uniform and to find hot spots where molds and/or insects are active.

Hudson Valley Hops and Grains

- 3 HP centrifugal fan
- 5 KW electric dryer (not show here)
- 28 ton / 1144 bu bin (933 bu soybean, 1000 bu wheat, 1144 bu barley)
- 9 ft diameter, 7 rings (31 ft to overall height)
- Metal building for cleaning, new building will be for processing
- ***Only clean and process as needed. No inventory to avoid pest build up.***





Heating Grain Bins

- Electric and propane heaters in-line with the bin fan
- Heat empty bins (140^{O} for 15 min.) to kill insects beneath the floor
- A well-designed system can dry grain in a bin without a separate dryer (if initial grain moisture is not too high) and sometimes without heated air.



Portable Radiant Heater



Arrowood Farm – batch dryer

- The dryer is set to maintain a specific temperature in the plenum. Each grain has particular temperature at which it can be dried to preserve germ, prevent cracking, etc.









Wilbur Knoll Farms

Top-bin Dryer

A wood heater supplements the propane top-bin dryer

- **6 – 8 cords/corn crop**
- **Saved $10K first year**
- **Propane burner stays on low**
- **Used for 15 years**



Notes

- In a top-bin dryer the grain is held at the top of the bin on a louvered floor. Hot air blows through the grain. Once it reaches the desired moisture, the louvers open and the grain drops to the bottom of the bin. It cools/gives off its heat at the bottom before it is transferred to a storage bin.
- Top-bin dryers are one of the most efficient drying systems.

Like drying hay bales, bags of grain can also be dried

- An older publication, “Drying and Storing Grain on the Farm” is available with other resources of this meeting.
- I do not know if nylon or burlap bag would allow the best in-bag drying.
- Ag bag grain system - https://www.farmshow.com/a_article.php?aid=33291



Fig. 1-A A large lot of wheat being dried with a hay drier fan. The fan is located just inside the barn door. The air duct inside the pile of bags is about 4 feet wide and 4 feet high. The depth of grain over the duct is the same as the width on each side of the duct.



Fig. 2-A A small lot of grain being dried with a small fan. The duct in this case is the size of the fan outlet.



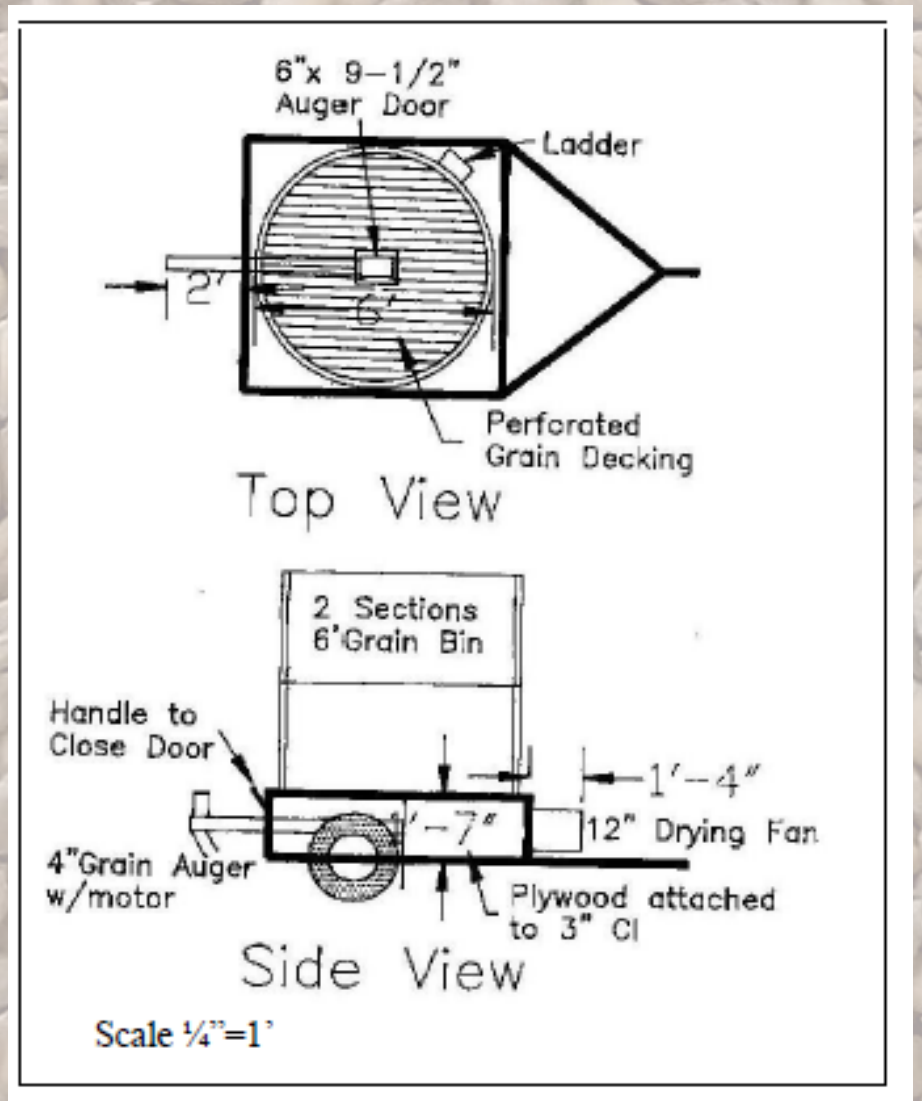
Red Rooster Farm – Portable Grain Dryer

SARE Project - Final report FNE16-854

- Culvert on a pallet
- Elevated aeration floor with port to blow in air

Portable Grain Dryer

Jack Lazor, Butterworks Farm







Argyle Craft Malts and Hops



Slits in floor cut with circular saw



Argyle Craft Malts and Hops

A simple bagger



Seed Cleaning

Size / density / shape / texture / stickiness / pubescence





- Seeds bounce differently too. An interesting old patent for a farmer fabricator https://patents.google.com/patent/US3036707
- Never as easy as it seems, but if you like to tinker and fabricate, then a simple and inexpensive cleaning system may be possible.

Kukon Brothers

- Any time you move bulk grain, there is an opportunity to clean it

grain cleaner incorporated into the bucket elevator to remove chaff.





Cyclone on back side of the grain cleaner



LMC size shaker

Fan removing chaff





Carter-Day Uni-flow Separator

Migliorelli Farm

- More than one cleaner may be needed
- Use fans at every opportunity to remove light chaff
- The Uni-flow separates 90% of vetch seed from rye, *slow*



Against the Grain Farm

- Running grain through a batch dryer without heat is a good way to clean it



Sosnowski Grain Cleaner

- “uses cebtrufugal air flow to clean grain”
- No screens to keep clean
- https://www.graincleanersoh.com/ws-grain-cleaners

Spiral Separators



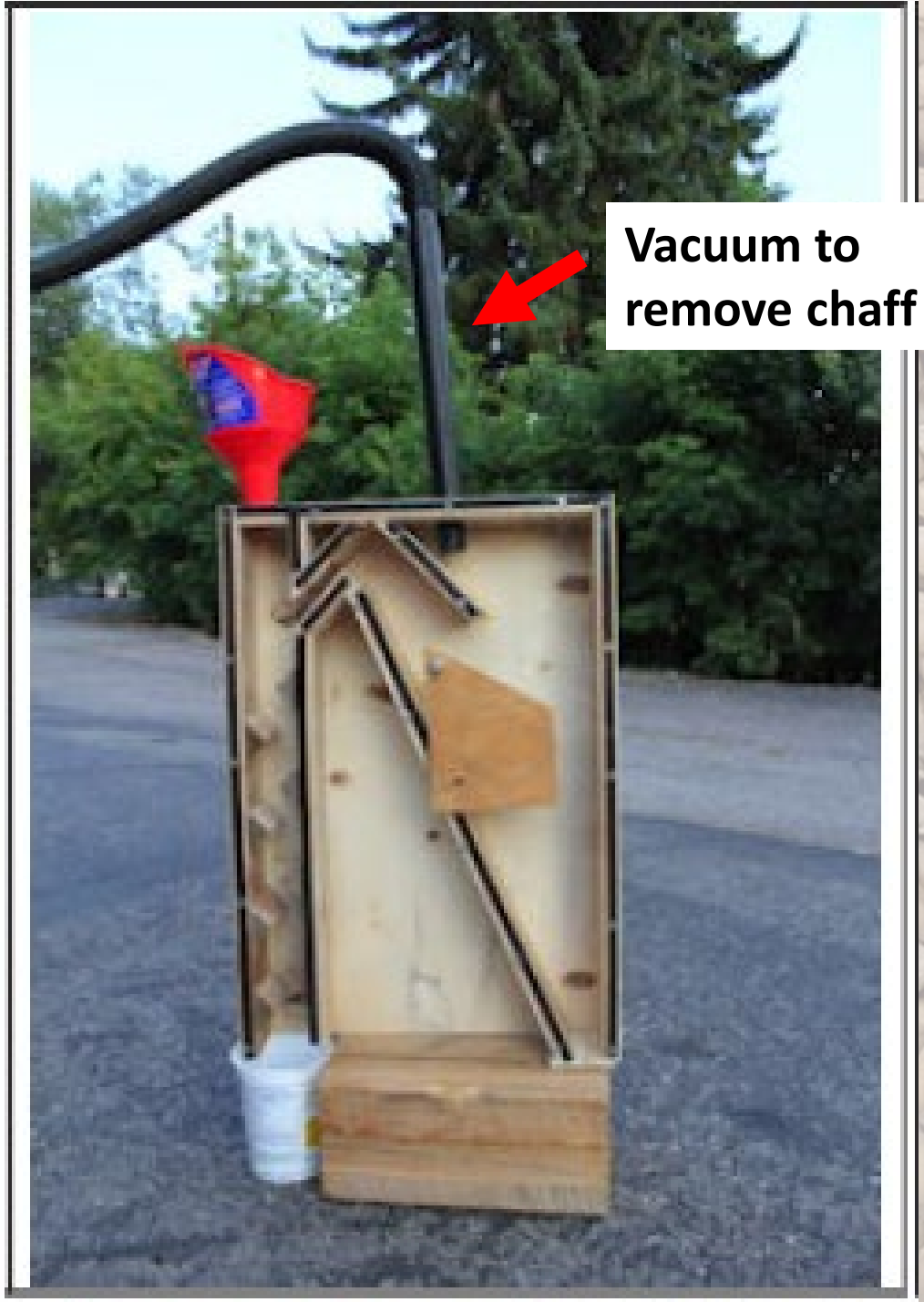
Double Spiral Separator



Single Spiral Separator

- Used by Hawthorne Valley Farm – said that it is slow
- Removes vetch seed from grains

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.hoffmanmfg.com%2Fproducts%2Fspiral-separators%2F&psig=AOvVaw26_j6MKZrKkzyUJBiPg6-L&ust=1603503036617000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCMDFubnIyewCFQAAAAdAAAAABAH



www.RealSeeds.co.uk

- Open-source plans for seed cleaner
- Designed for small amounts of garden seed
- Can be adapted to bounce seed down a shaft and add air to clean larger quantities of grain???



Fanning Mill type cleaner

- Two shaking screens and a blower
- Old equipment is laying around barns un-used waiting to be found

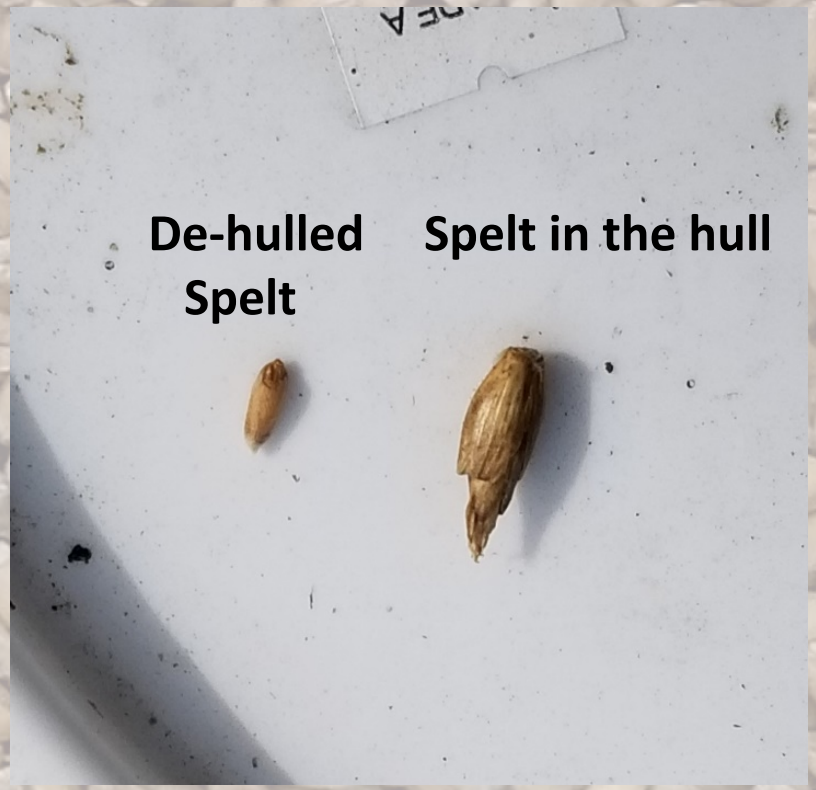
Mechanical Seed Cleaning and Handling
Agricultural Handbook #354

- 58 pages
- >20 types of seed cleaners described
- 7 types of seed handling machines
- https://www.roguenativeplants.org/mechanical-seed-cleaning-and-handling-agricultural-handbook-no-354/

Grain Storage, Cleaning, and Drying

Know the characteristics of your grain

- Air flows better through spelt with hulls
- Spelt with hulls moves slowly through augers
- Etc.



Manuals on Grain Storage and Drying

- Grain Drying, Handling, and Storage Handbook, MWPS-13
- Dry Grain Aeration Systems Design Handbook, MWPS-29
- Managing Dry Grain in Storage
- @ https://www-mwps.sws.iastate.edu/catalog/grain-handling-storage

- North Dakota State University website, https://www.ag.ndsu.edu/graindrying
- University of Nebraska, https://lancaster.unl.edu/ag/crops/storage.shtml

Websites for Do-It-Yourselfers

- https://www.farmshow.com/
- https://farmhack.org/tools

- CAAHP blog with these resources, http://blogs.cornell.edu/capitalareaagandhortprogram/2020/10/26/grain-storage-drying-and-cleaning-systems/

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NORTHEAST ORGANIC FARMING ASSOCIATION NEW JERSEY

Grain Cleaning, Drying, and Storage Systems

Sponsored by:

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